OLD DOMINION UNIVERSITY RESEARCH FOUNDATION

DEPARTMENT OF ELECTRICAL ENGINEERING
SCHOOL OF ENGINEERING
OLD DOMINION UNIVERSITY
NORFOLK, VIRGINIA

AIRBORNE ANTENNA PATTERN CALCULATIONS

By

Ali B. Bagherian

and

Roland R. Mielke, Principal Investigator

Final Report
For the period November 1, 1982 to October 31, 1983

Prepared for the
National Aeronautics and Space Administration
Langley Research Center
Hampton, Virginia

Under
Research Grant NSG 1655
Melvin C. Gilreath, Technical Monitor
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P.O. Box 6369
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ABSTRACT

Use of calculation program START and modeling program P3D to produce radiation patterns of antennas mounted on space station is discussed. Basic components of two space stations in the early design stage are simulated and radiation patterns for antennas mounted on the modules are presented.

ACKNOWLEDGMENT

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AIRBORNE ANTENNA PATTERN CALCULATIONS

By

Ali B. Bagherian[1], and Roland R. Mielke[2]

INTRODUCTION

The Program START has proven to be a powerful tool in computer generation of airborne antenna patterns for antennas mounted on the fuselage of general aviation aircraft. The calculation Program START produces airborne antenna radiation patterns that closely approximate the experimentally measured radiation patterns. See references (1-2). This approach has cost and time advantages over experimental measurement procedures for generating airborne antenna radiation patterns.

The Program START is currently being modified to produce radiation patterns for antennas mounted on space stations. The geometrical structure of the space station is more complex than general aviation aircraft and it demands more powerful calculation and modeling programs.

The proposed procedure to assemble the space station in the earth orbit is first to place the main module and two solar panels in synchronous orbit and then to add other parts by use of the space shuttle. Therefore, it is important to study the antenna radiation patterns at various degrees of completeness of the space station. That is, we first simulate the main module of the space station using the modeling Program P3D and study the radiation patterns of antennas mounted on the main module. Next, two plates are added to simulate two long solar panels and the above analysis is repeated. We then gradually add more plates to simulate other parts of the space station and calculate the resulting antenna patterns.

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At present the modeling program P3D can handle one prolate spheroid to simulate the cylindrical configuration of the main module and a limited number of plates to simulate two solar panels and other parts. The calculation program START can accept one prolate spheroid and up to twenty-five plates to produce antenna radiation patterns. At this point there is a need to improve both the modeling and the calculation programs so that they can handle more than one prolate spheroid. There is also a need to increase the number of plates that both programs can accept.

To investigate the feasibility of using the existing modeling program P3D and calculation program START, a series of simulations of basic components of the space station are presented. The investigation includes axial slot antennas located on the main module of the space station.

A description and definition of input data required by Programs START and P3D are given in reference (2). The discussion of the use of interactive program P3D and an example of a modeling routine on the NASA/Langley Research Center computer system are also presented in reference (2).

II. SIMULATION OF MAIN MODULE

The main module is first simulated by a long prolate spheroid and then truncated at the appropriate location to obtain a cylinder which has nearly straight edges. The solar panels are simulated by two plates. These plates are either attached or not attached to the cylinder (main module) depending on the design of the space station.

The following frequency ranges are used for antenna radiation patterns: .2 GHZ, .25 GHZ, 1 GHZ, 1.6 GHZ, 2.2 GHZ, 10 GHZ, 25 GHZ and 30 GHZ. Figure

II.1. shows the dimensions of the main module and the proposed antenna locations. Figure II.2. shows the schematics of the long prolate spheroid used on the graphics tablet to simulate the main module. The side, front and top views of the simulated prolate spheroid are shown in figures II.3, II.4 and II.5. This prolate spheroid is truncated at ± 270' along the z-axis. The side, front and top views of the resulting cylinder with straight edge bases are shown in Figures II.7, II.8 and II.9.

III. TEST PATTERNS FOR PROPOSED SPACE STATIONS IN EARLY DESIGN STAGE

III.1 INTRODUCTION

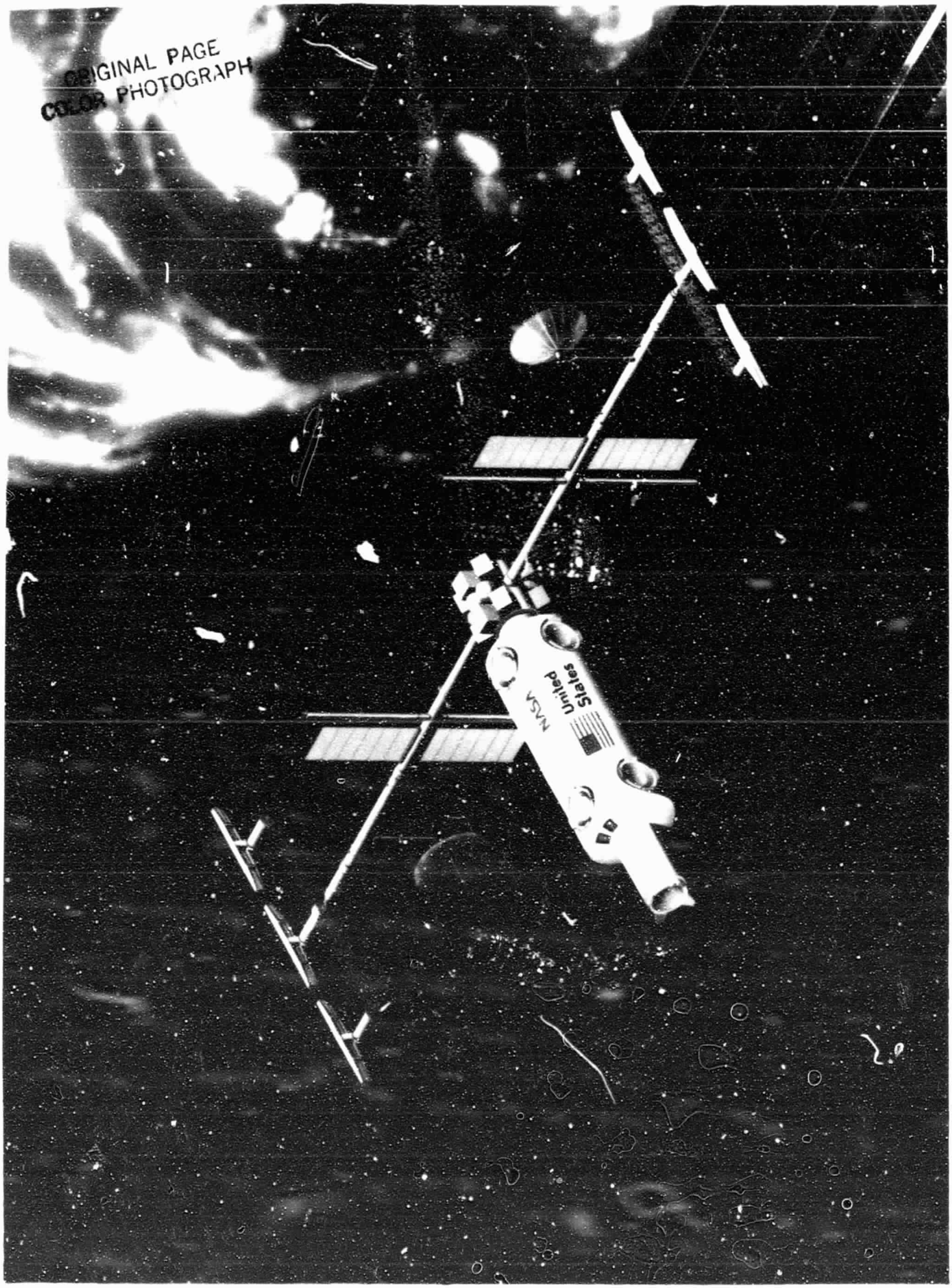
Two proposed space stations in the early design stage are simulated in this section. The first simulation model consists of one main module and two long straight solar panels. The second simulation model has three modules, two diagonal solar panels and bottom truss platform.

For each preliminary design the model is simulated first and then radiation patterns for antennas mounted on the module are presented. Next the other parts of the space station are gradually added and then simulated.

III.2. Main Module With Two Long Solar Panels

The artist's conceptual drawing of the first space station with two long solar panels is shown in the next picture. As seen in this picture, the geometrical structure is complex. However, the components that most affect the antenna radiation patterns are the main module and two long solar panels. Simulation of these components of the space station is presented in this section.

The following simulation information concerning the dimensions of four corners of each long solar panel is easily obtained from dimensions of space



station shown in Figure III.2-1. This data is simply input as mathematical model input data manually as required by the "PG:" command:

```
PG:  Left Solar Panel
     4F
     0.      720.     -360.
     0.     4320      -360.
     0.     4320.      360.
     0.      720.      360.

PG:  Right Solar Panel
     4F
     0.     -720.      360.
     0.     -4320.     360.
     0.     -4320.    -360.
     0.     - 720.    -360.
     these dimensions are in inches.
```

The modeling program simulates the main module completely when the long prolate spheroid is truncated out ± 270'. along the z-axis. This is done by "FC:" command as follows:

```
     FC:
      T  T
     270.    -270.
```

Figure III.2-1. shows the dimensions of the main module and two long solar panels. The side, front and top views of the simulation of the main module with solar panels are shown in Figures III.2-3., III.2-4 and III.2-5.

The principal roll plane patterns for axial slot antennas on the main

module with and without two long solar panels are presented in this section. Also, the principal roll plane patterns for axial slot antennas for the following multiple antenna locations are displayed:
one antenna on the top of main module, two antennas on the top and the bottom of main module and four antennas around the main module.

III.3 Three Modules With Two Diagonal Solar Panels and Bottom Truss Platform

Basic components of the second space station model shown in Figure III.3-1. are simulated in this section. The components that most affect antenna radiation patterns are modules, solar panels and platforms.

The coordinates of each corner of the diagonal solar panels and the bottom truss platform are easily obtained from the dimensions of the preliminary design of the space station shown in Figure III.3-1. This information is put in the mathematical model input data manually as required by the "PG:" command.

The principal roll plane patterns for an axial slot antenna on top of the main module with two diagonal solar panels are then presented. The simulation of the space station continues with the addition of the bottom truss platform. Then, two more modules are added by translation of the origin of the coordinate axis as shown in Figure III.3-9. using command "RT:" and rotation of the coordinate axis around the translated origin as seen in Figure III.3-10. using command "PD:". See reference (2) for explanations of commands "RT:" and "PD:". Note that geometrical structure is not rotated. Finally, principal roll plane patterns of axial slot antennas at various locations are presented.

REFERENCES

1. Bagherian, Ali B.; and Mielke, Roland R.: Airborne Antenna Pattern Calculations. Progress Report, NASA Research Grant NSG-1655, Aug. 1983.

2. Owens, Teri M.; Bagherian, Ali B.; and Mielke, Roland R.: Airborne Antenna Pattern Calculations. Final Report, NASA Research Grant NSG-1655, Dec. 1982.

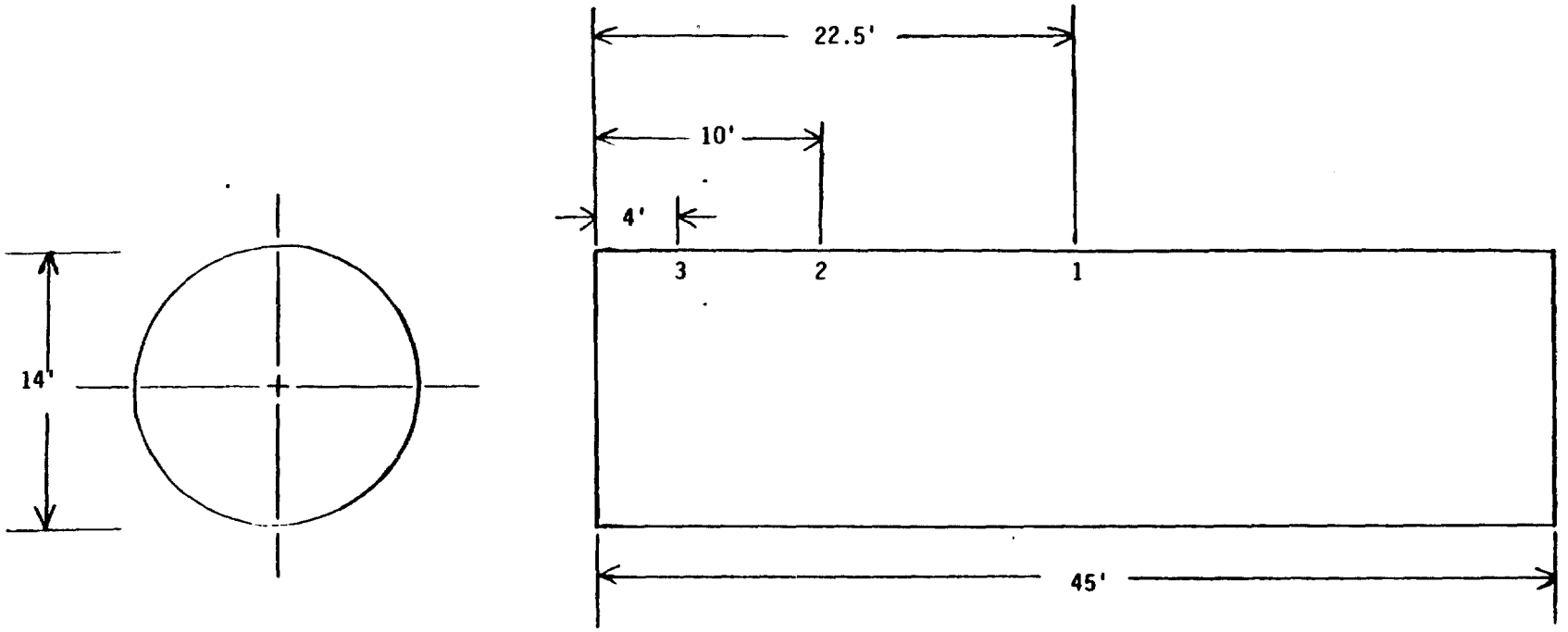


Figure II.1. Dimensions of main module configuration (cylinder) and proposed antenna locations 1, 2 and 3.

Scale Factor = 288

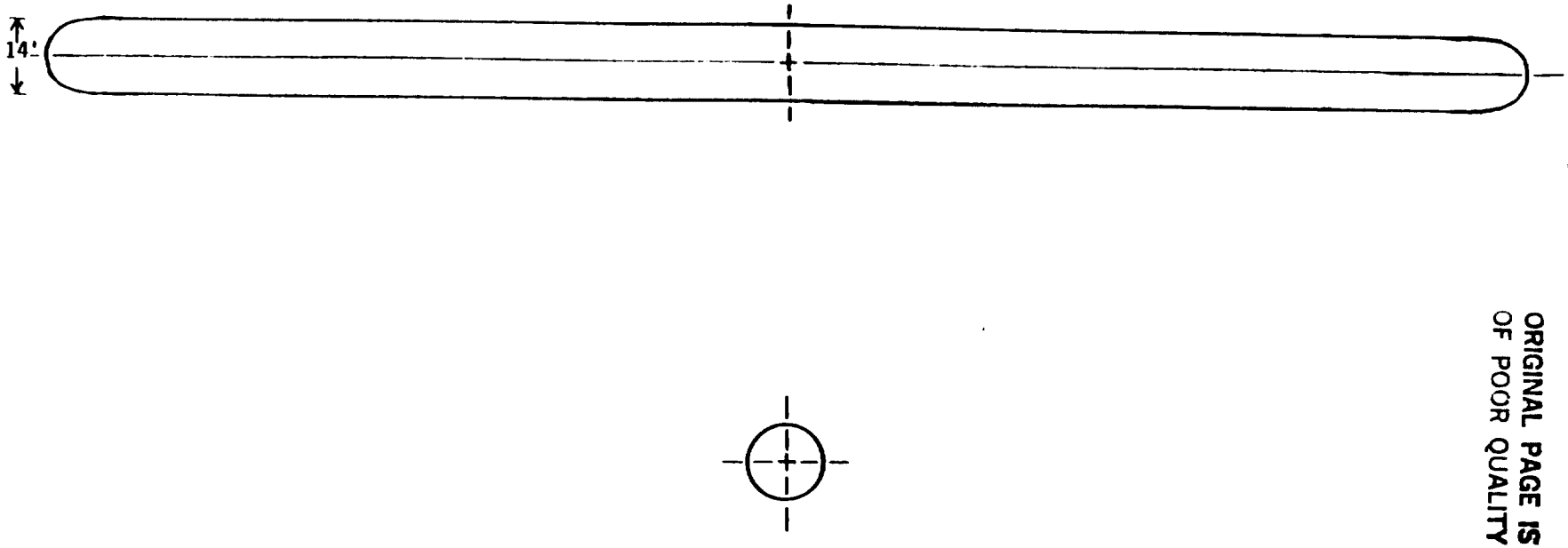


Figure II.2. Schematics of the long prolate spheroid used on graphics tablet system to simulate the main module.

LONG PROLATE SPHEROID TO SIMULATE THE MAIN MODULE.
FUSELAGE PROFILE
(ELEVATION PLANE)

S. F. = 200.000

Figure II.3. Long prolate spheroid. Side view.

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OF POOR QUALITY

LONG PROLATE SPHEROID TO SIMULATE THE MAIN MODULE.
CROSS SECTION
(ROLL PLANE)

S. F. = 200.000

Figure II.4. Long prolate spheroid. Front view.

LONG PROLATE SPHEROID TO SIMULATE THE MAIN MODULE.
HERDING PROFILE
(AZIMUTH PLANE)

S. F. = 200.000

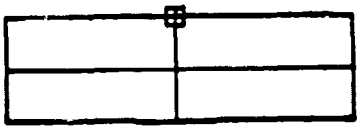
Figure II.5. Long prolate spheroid. Top view.

ORIGINAL PAGE IS
OF POOR QUALITY

```
FG·
 84.0 1763.5 1763.5
 0. 0. 0.
FC·
 T T
 270.0 -270.0
EX·
END OF FILE
?? E
SLTV1    IS A LOCAL FILE
/
```

Figure II.6. Mathematical model input data for main module.

SIMULATED MAIN MODULE
FUSELAGE PROFILE
(ELEVATION PLANE)



S. F. = 200.000

Figure II.7. Simulation of main module. Side view.

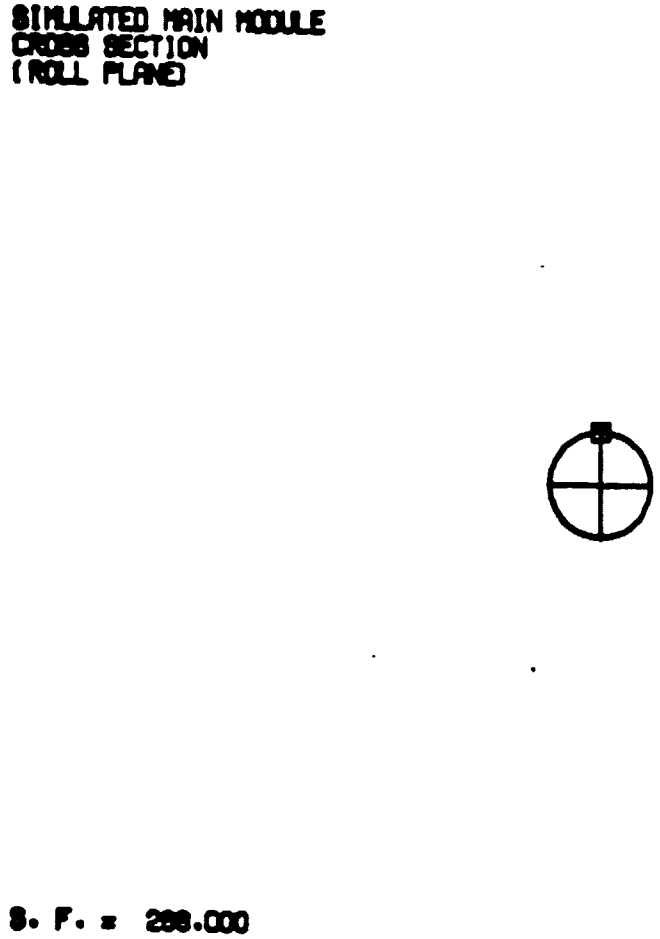
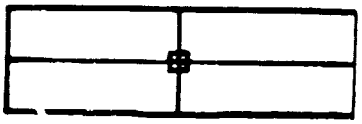


Figure II.8. Simulation of main module. Front view.

SIMULATED MAIN MODULE
HERDING PROFILE
(AZIMUTH PLANE)



S. F. = 200.000

Figure II.9. Simulation of main module. Top view.

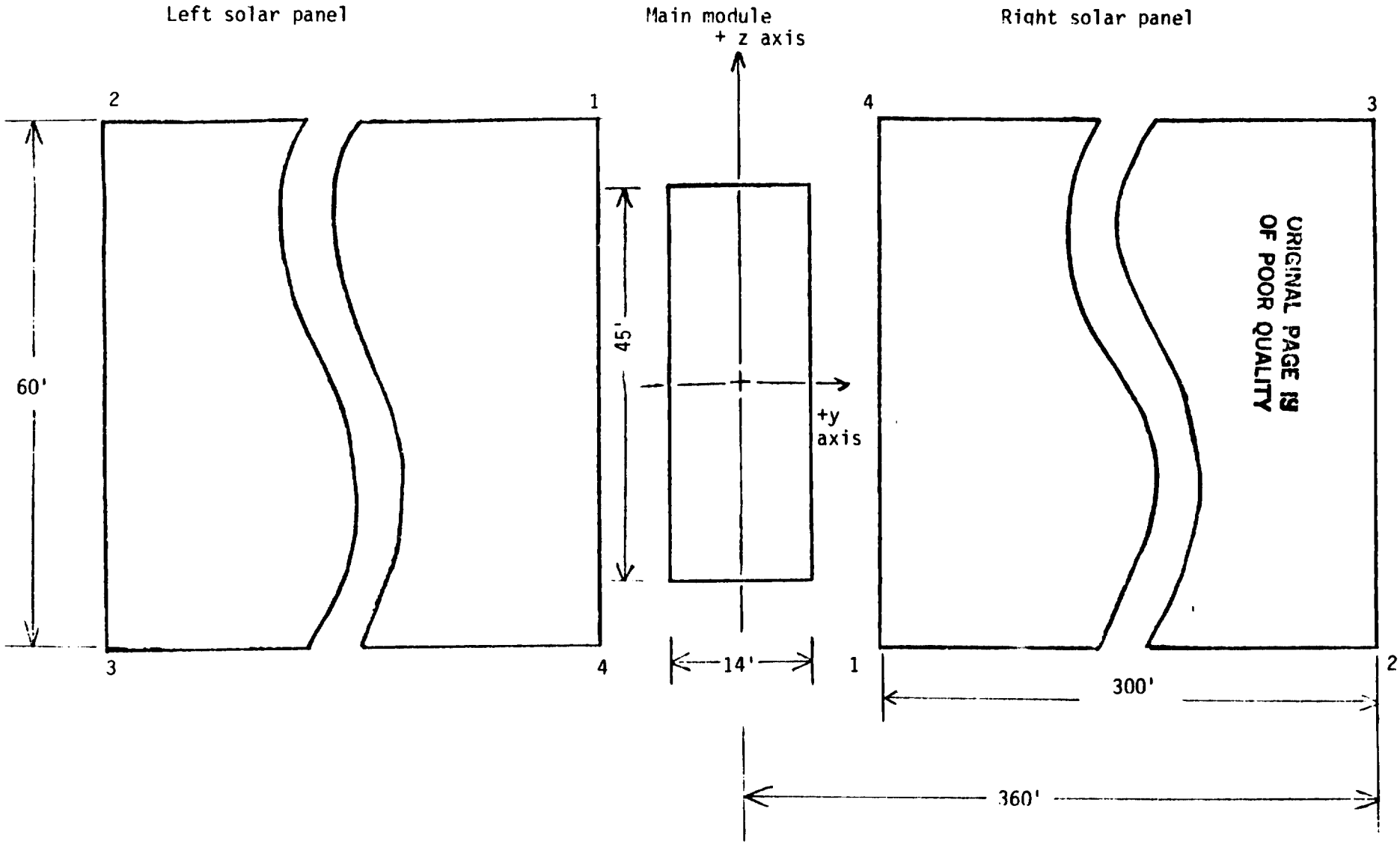


Figure III.2-1. Dimensions of main module with two long solar panels.

```
FQ·MAIN MODULE WITH SOLAR PANELS.
 84.0 1763 5 1763 5
 0. 0. 0.
FC·
 T T
 270 0 -270 0
PG·LEFT SOLAR PANEL
 4 F
 0. 720. -360.
 0. 4320. -360.
 0. 4320. 360.
 0. 720. 360.
PG·RIGHT SOLAR PANEL
 4 F
 0. -720. 360.
 0. -4320. 360.
 0. -4320. -360.
 0. -720. -360.
SG·
 0. 0.
 1
 0. 0.
 .01 .5 0. 0 1
 1. 0
FQ· 26 GHZ
 1 26 1
PP·
 3.75 3
PD·ROLL PLANE
 0. 90.
 90 91 2
 0 360 1
 T 50000
 F 3
EX·
FQ·2.2 GHZ
 1 2.2. 1.
EX·
FQ·25 GHZ
 1 25 1.
EX·
END OF FILE
??
```

Figure III.2-2. Mathematical model input data for main module with two long solar panels.

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OF POOR QUALITY

SPACE STATION WITH TWO LONG SOLAR PANELS.
FUSELAGE PROFILE
(ELEVATION PLANE)

S. F. = 200.000

Figure III.2-3. Slot antenna on top of main module with two long solar panels. Side view.

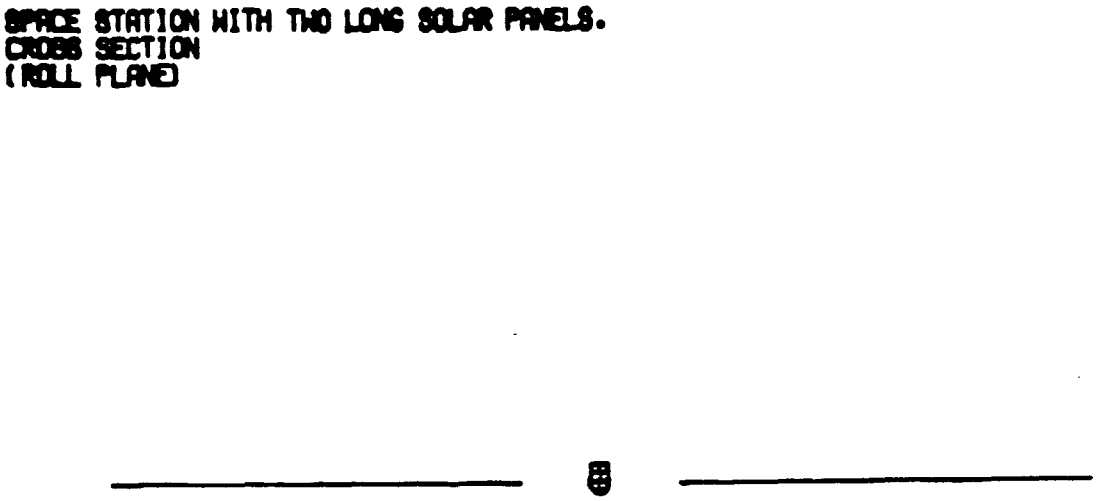


Figure III.2-4. Slot antenna on top of main module with two long solar panels. Front view.

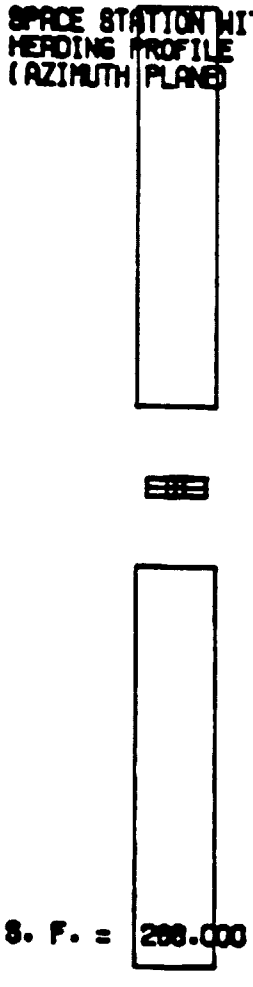
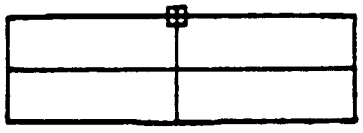


Figure III.2-5. Slot antenna on top of main module with two long solar panels. Top view.

```
FG
 84 0 1763 5 1763 5
 0  0  0
PP
 3.75 3
FC
 T T
 270 0 -270 0
SG
 0  0
 1
 0  0
 .01  5 0  0  1
 1  0
FQ 2 GHZ
 1  2 1
PD ROLL PLANE
 0  90
 90 91 2
 0 360 1
 T 50000
 F 3
EX
PD ELEVATION PLANE
 90  90
 90 91 2
 0 360 1
 T 50000
 F 3
EX
FQ 10 GHZ
 1 10  1
PD ROLL PLANE
 0  90
 90 91 2
 0 360 1
 T 50000
 F 3
EX
PD ELEVATION PLANE
 90  90
 90 91 2
 0 360 1
 T 50000
 F 3
EX
FQ 30 GHZ
 1 30  1
PD ROLL PLANE
 0  90
 90 91 2
 0 360 1
 T 50000
 F 3
EX
PD ELEVATION PLANE
 90  90
 90 91 2
 0 360 1
 T 50000
 F 3
EX
END OF FILE
?? E,,RL
SS123   REPLACED
SS123   IS A LOCAL FILE
/
```

Figure III.2-6. Mathematical model input data of main module. Antenna location 1.

SIMULATION OF MAIN MODULE.
FUSELAGE PROFILE
(ELEVATION PLANE)



S. F. = 200.000

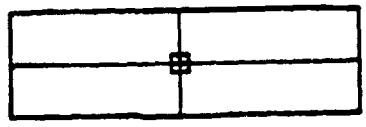
Figure III.2-7. Antenna location 1 on the main module. Side view.

SIMULATION OF MAIN MODULE.
CROSS SECTION
(ROLL PLANE)

S. F. = 200.000

Figure III.2-8. Antenna location 1 on the main module. Front view.

SIMULATION OF MAIN MODULE.
HEADING PROFILE
(AZIMUTH PLANE)



S. F. = 200.000

Figure III.2-9. Antenna location 1 on the main module. Top view.

E--PHI
DB PLOT

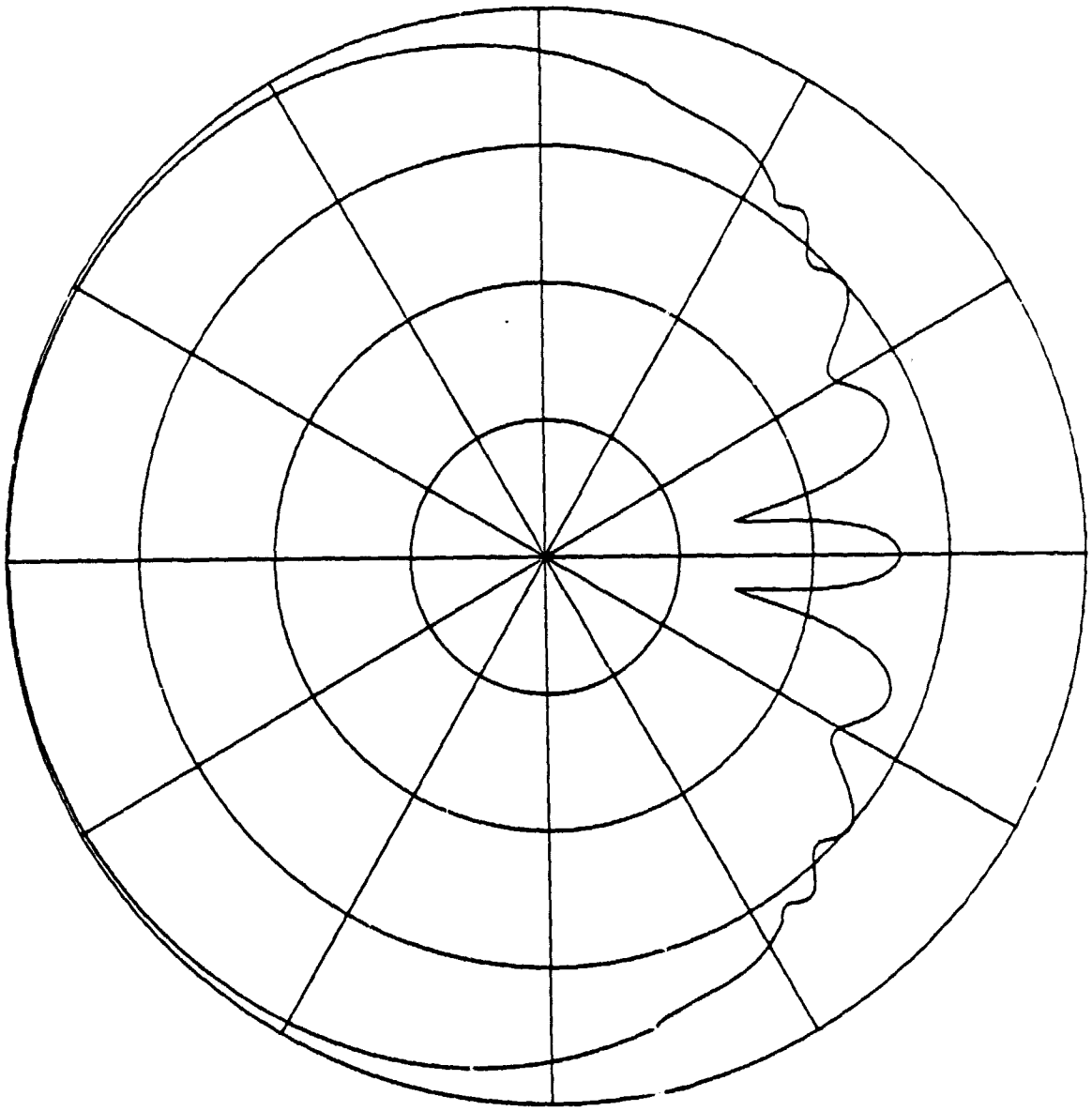


Figure III.2-10. Principal roll plane pattern at .2 GHZ. Axial slot antenna at location 1, without solar panels.

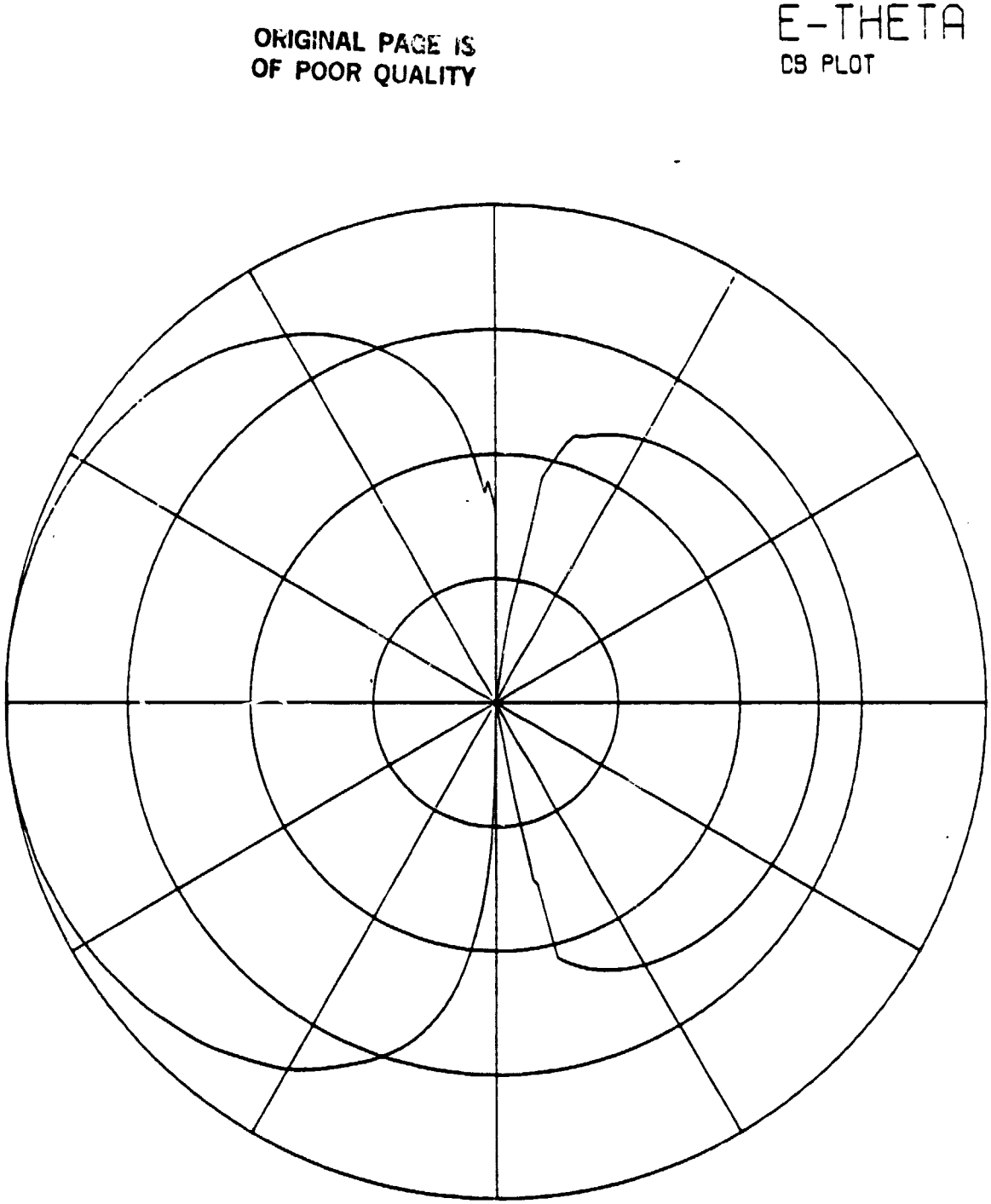


Figure III.2-11. Principal elevation plane pattern at .2 GHZ. Axial slot antenna at location 1, without solar panels.

E-PHI
DB PLOT

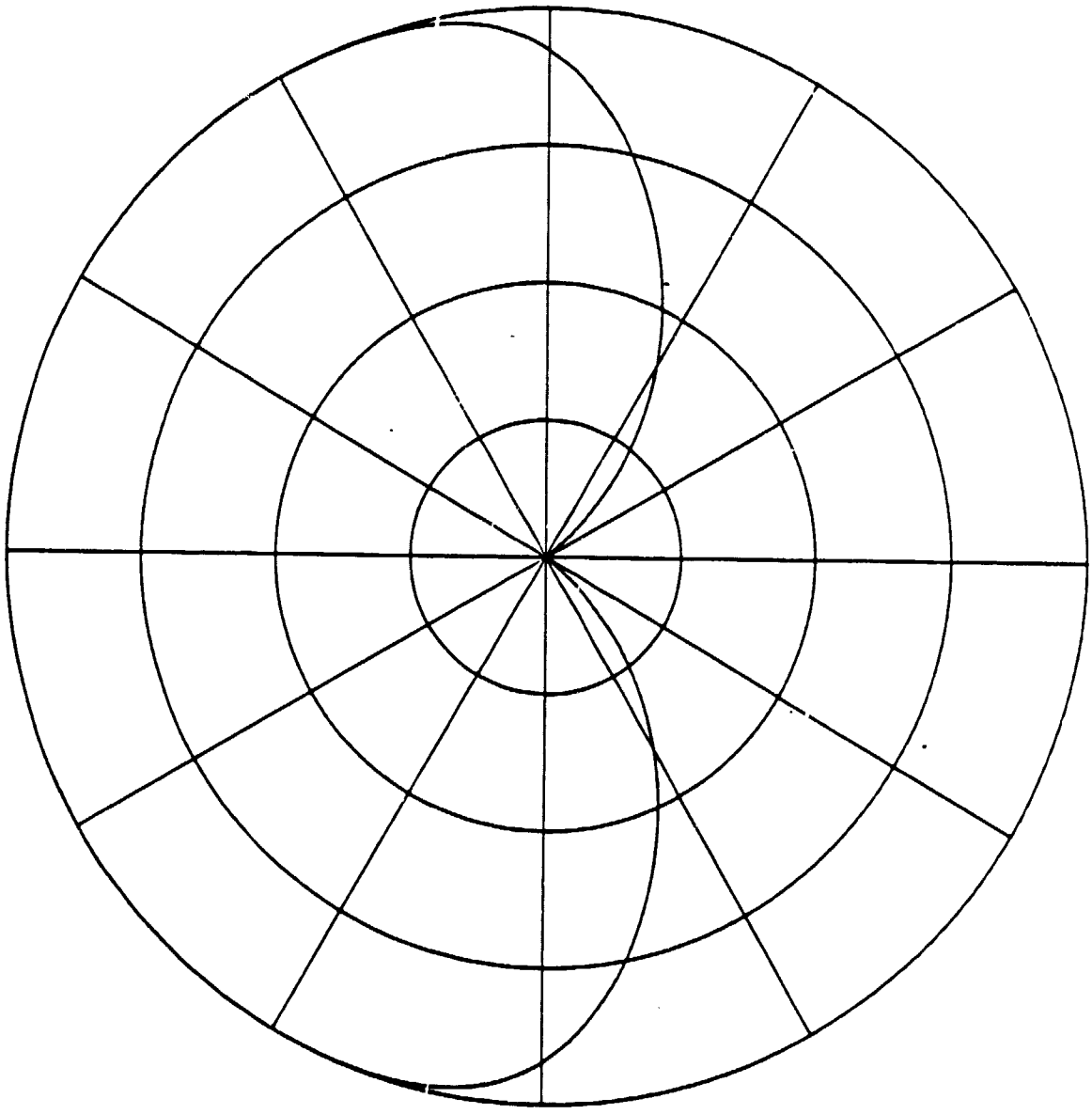


Figure III.2-12. Principal roll plane pattern at 10 GHZ. Axial slot antenna at location 1, without solar panels.

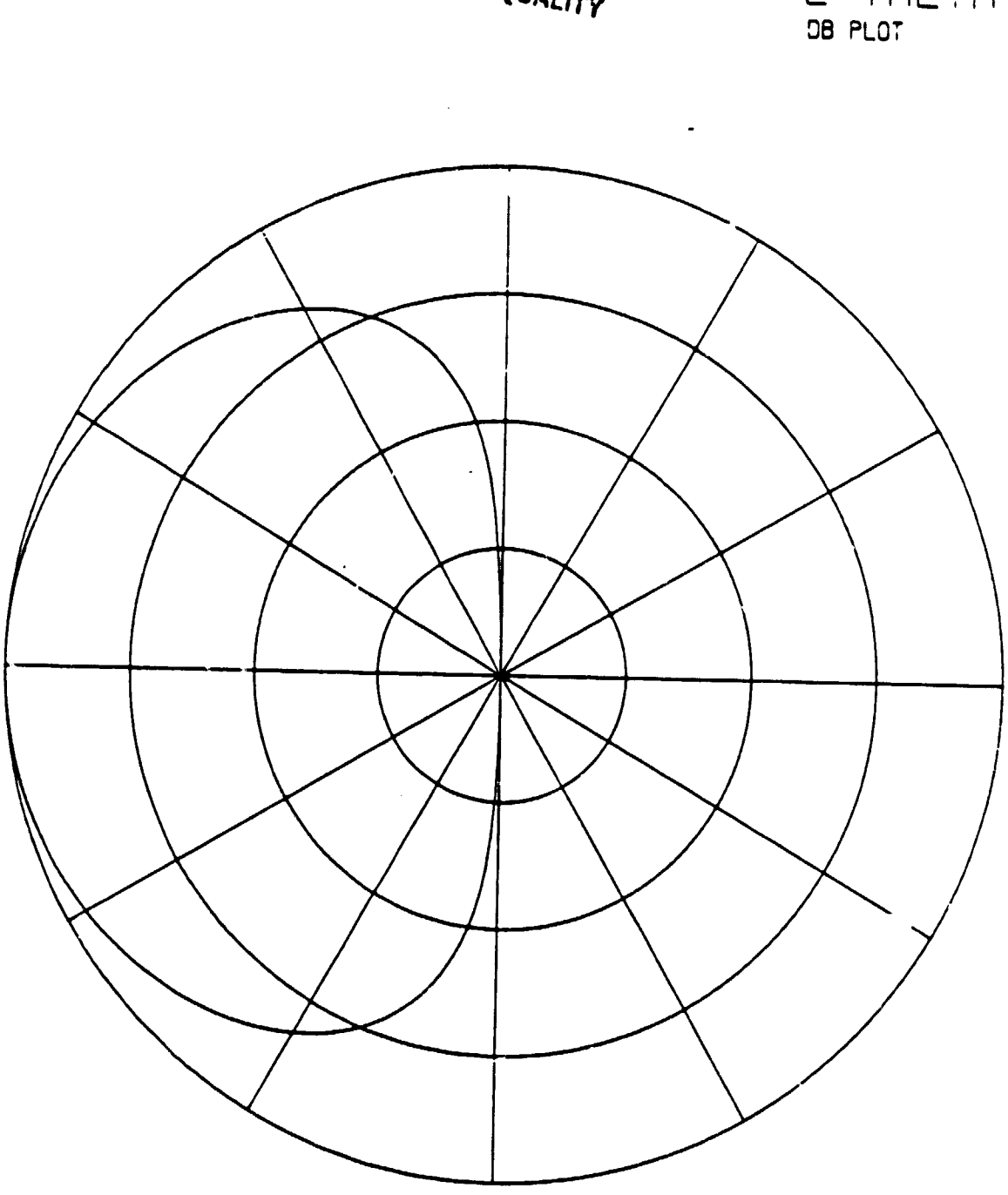


Figure III.2-13. Principal elevation plane pattern at 10 CHZ. Axial slot antenna at location 1, without solar panels.

E-PHI
DB PLOT

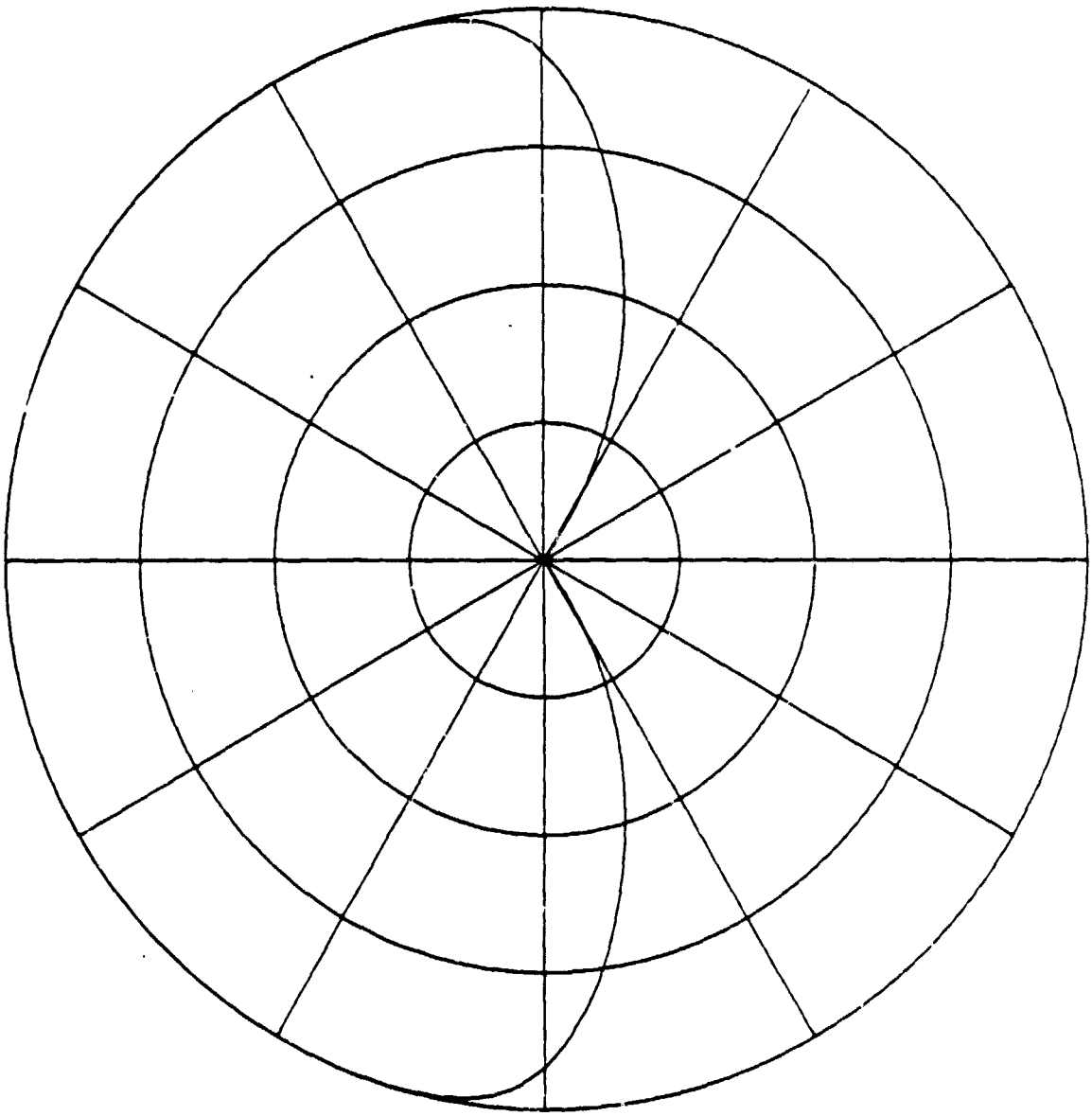


Figure III.2-14. Principal roll plane pattern at 30 GHZ. Axial slot antenna at location-1, without solar panels.

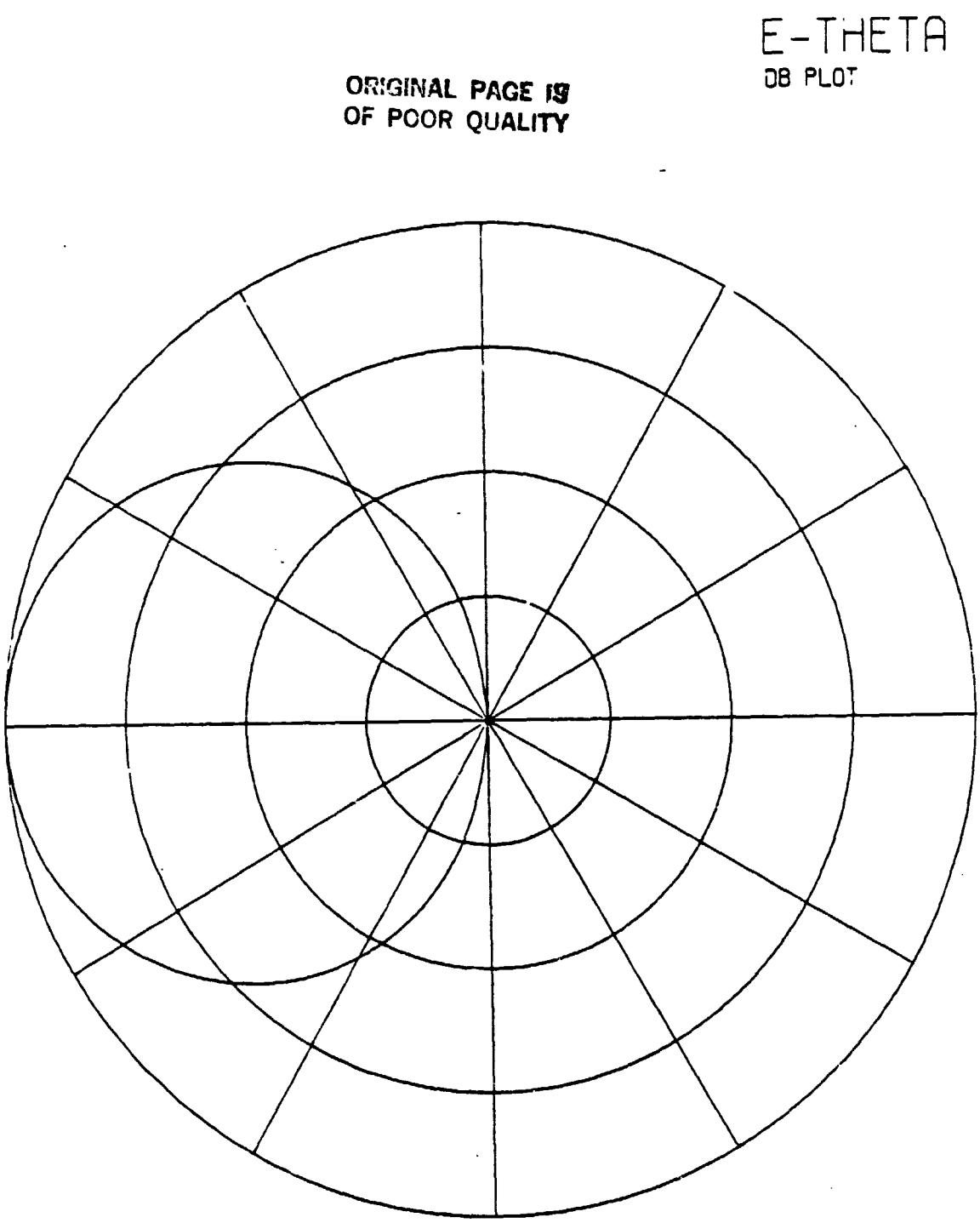
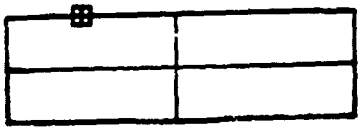


Figure III.2-15. Principal elevation plane pattern at 30 GHZ. Axial slot antenna at location 1, without solar panels.

```
FG
 84 0 1763 5 1763 5
 0. 0. 0.
PP
 3 75 3
FC
 T T
 270 0 -270 0
SG
 0  -150
 1
 0. 0
  .01  .5 0  0. 1
 1. 0.
FQ 1 6 GHZ
 1 1 6 1
PD
 0. 90
 90 91 2
 0 360 1
 T 50000
 F 3
EX
PD
 90  90
 90 91 2
 0 360 1
 T 50000
 F 3
EX
END OF FILE
?? E
$S123   IS A LOCAL FILE
/
```

Figure III.2-16. Mathematical model input data of main module. Antenna location 2.

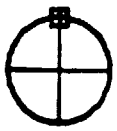
SIMULATION OF MAIN MODULE.
FUSELAGE PROFILE
(ELEVATION PLANE)



S. F. = 200.000

Figure III.2-17. Antenna location 2 on the main module. Side view.

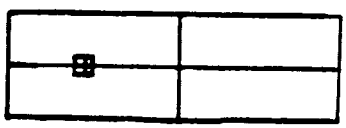
SIMULATION OF MAIN MODULE.
CROSS SECTION
(ROLL PLANE)



S. F. = 200.000

Figure III.2-18. Antenna location 2 on the main module. Front view.

SIMULATION OF MAIN MODULE.
HEADING PROFILE
(AZIMUTH PLANE)



S. F. = 200.000

Figure III.2-19. Antenna location 2 on the main module. Top view.

E-PHI
DB PLOT

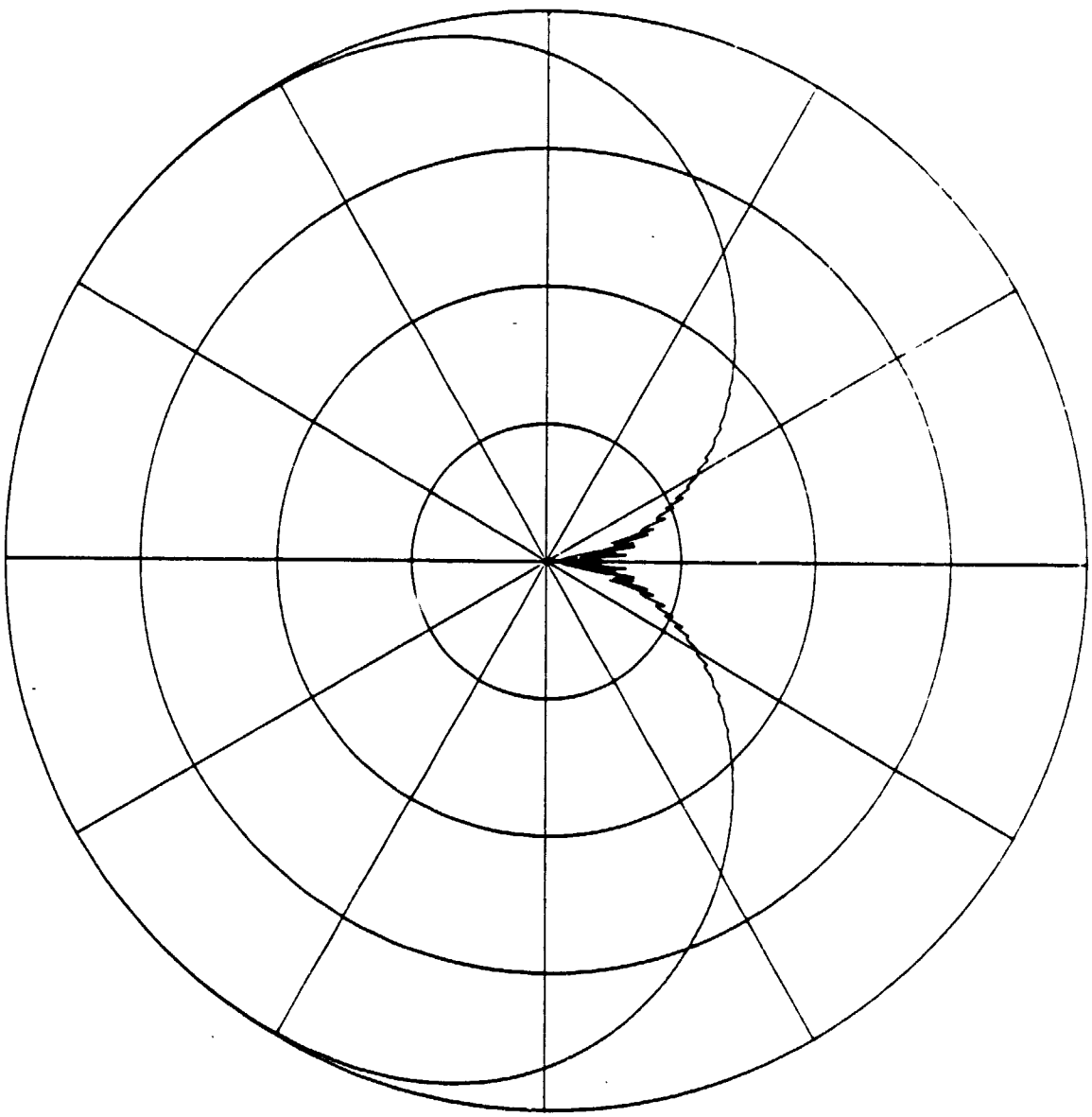


Figure III.2-20. Principal roll plane pattern at 1.6 GHZ.
Axial slot antenna at location 2.

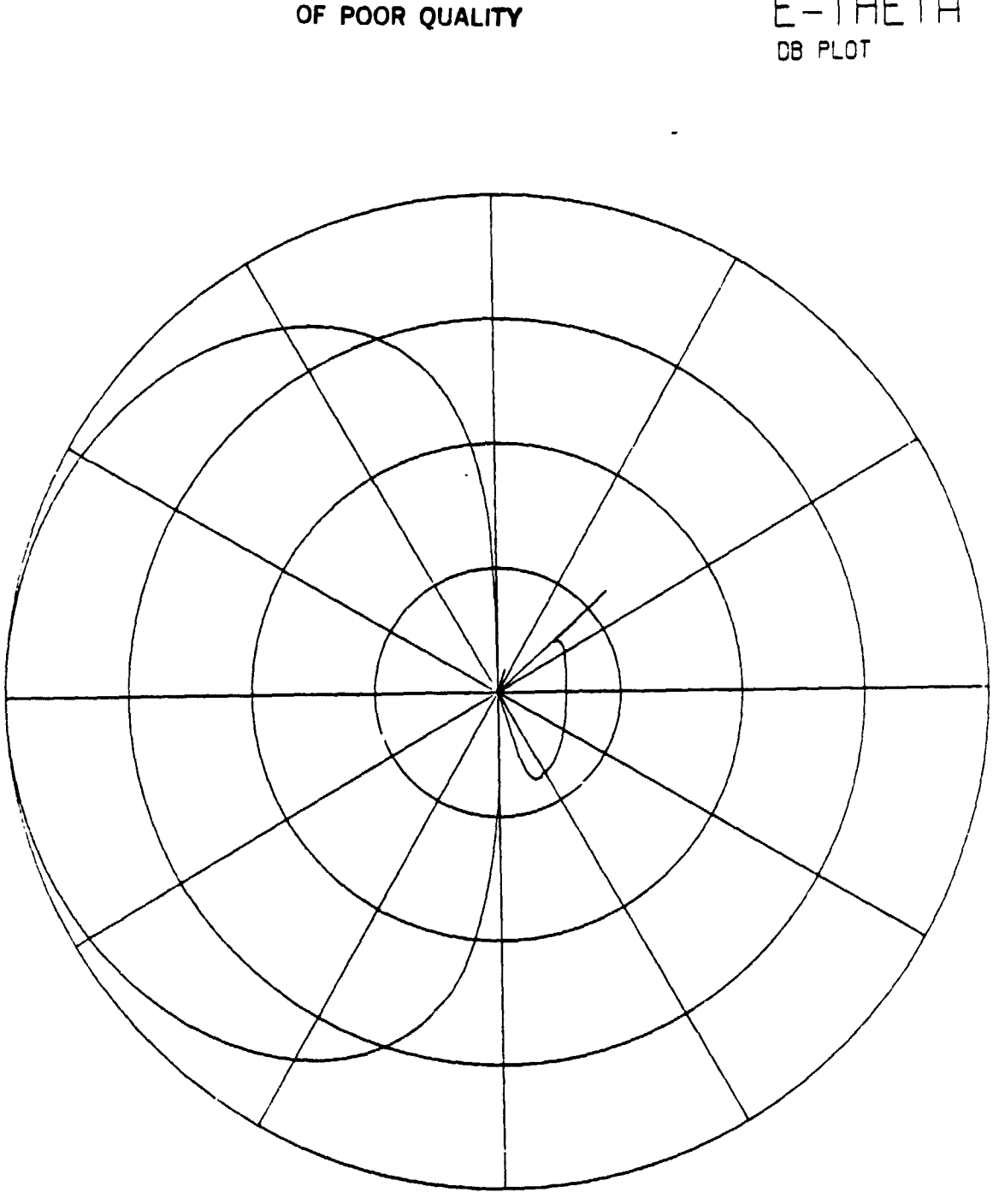


Figure III.2-21. Principal elevation plane pattern at 1.6 GHZ. Axial slot antenna at location 2.

```
FG
 84 0 1763 5 1763 5
 0  0  0
PP
 3 75 3
FC
 T T
 270 0 -270 0
SG
 0  -222
 1
 0  0
  01  5 0  0  1
 1  0
FQ 1  GHZ
 1 1  1
PD ROLL PLANE
 0  90
 90 91 2
 0 360 1
 T 50000
 F 3
EX
PD ELEVATION PLANE
 90  90
 90 91 2
 0 360 1
 T 50000
 F 3
EX
END OF FILE
?? E
SS123   IS A LOCAL FILE
/
```

Figure III.2-22. Mathematical model input data of main module. Antenna location 3.

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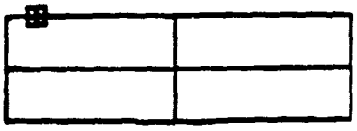
OF POOR QUALITY

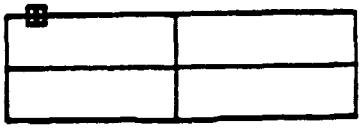
SIMULATION OF MAIN MODULE.
FUSELAGE PROFILE
(ELEVATION PLANE)



S. F. = 200.000

Figure III.2-23. Antenna location 3 on the main module. Side view.

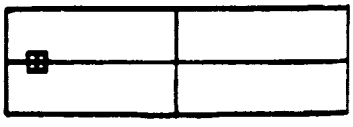
SIMULATION OF MAIN MODULE.
FUSELAGE PROFILE
(ELEVATION PLANE)



S. F. = 200.000

Figure III.2-24. Antenna location 3 on the main module. Front view.

SIMULATION OF MAIN MODULE.
HERDING PROFILE
(AZIMUTH PLANE)



S. F. = 200.000

Figure III.2-25. Antenna location 3 on the main module. Top view.

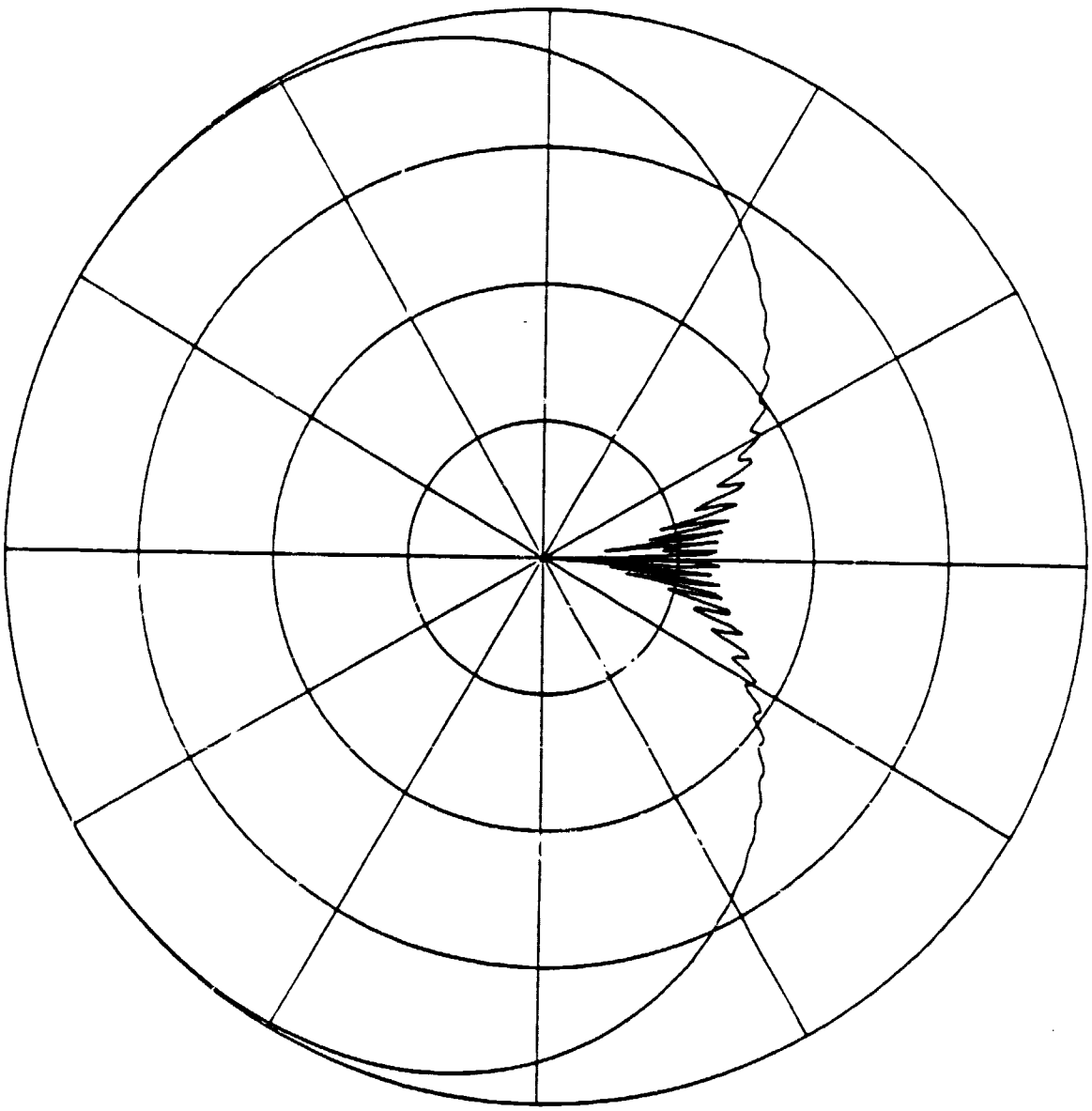


Figure III.2-26. Principal roll plane pattern at 1 GHZ. Axial slot antenna at location 3, without solar panels.

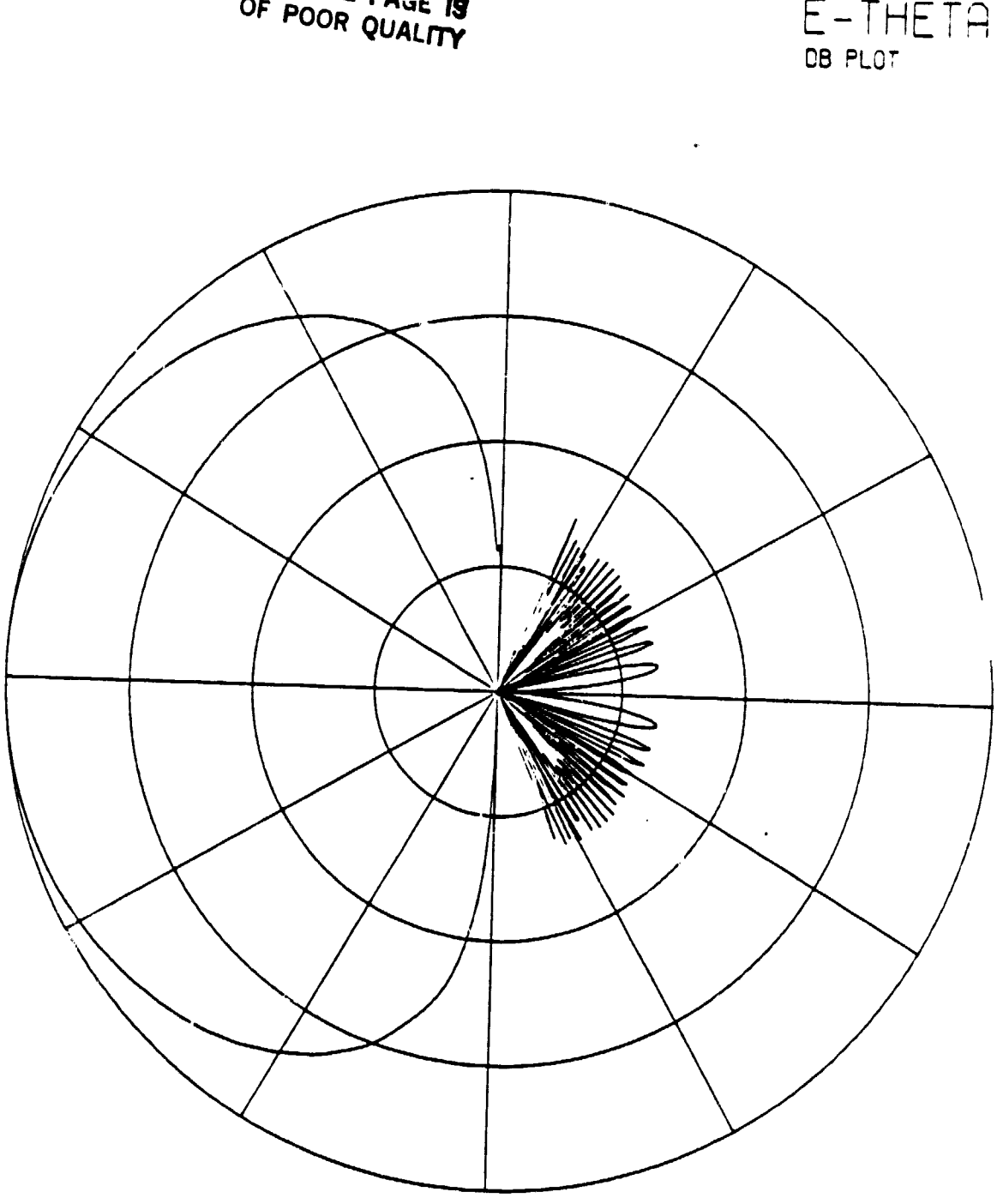
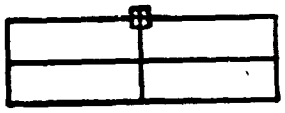


Figure III.2-27. Principal elevation plane pattern at 1 GHZ. Axial slot antenna at location 3, without solar panels.

```
FG MAIN MODULE WITHOUT SOLAR PANELS.
 84 0 1763 5 1763.5
 0. 0. 0.
PP.
 3.75 3
FC.
 T T
 270 0 -270 0
SQ.
 0  0
 1
 0. 0
  .01  5 0. 0  1
 1.
FQ. 26 GHZ
 1  26 1
PD.
 0.  1
 90 91 2
 0 360 1
 T 50000
 F 3
EX.
SP.
 T 1  0
PD.
 0. 179 8
 90 91 2
 0 360 1
 T 50000
 F 3
EX.
SQ.
 90. 0.
 1
 0. 0.
  .01  .5 0. 0. 1
 1. 0.
EX.
PD.
 0. 0.
 90 91 2
 0 360 1
 T 50000
 F 3
EX.
END OF FILE
?? E
SLTV1    IS A LOCAL FILE
/
```

Figure III.2-28. Mathematical model input data of main module without solar panels for multiple antennas.

MAIN MODULE OF SPACE STATION.
FUSELAGE PROFILE
(ELEVATION PLANE)



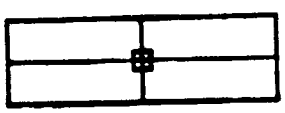
S. F. = 200.000

Figure III.2-29. Axial slot antenna on top of main module without solar panels. Side view.

MAIN MODULE OF SPACE STATION.
CROSS SECTION

Figure III.2-30. Axial slot antenna on top of main module without solar panels. Front view.

MAIN MODULE OF SPACE STATION.
HERDING PROFILE
(AZIMUTH PLANE)



S. F. = 200.000

Figure III.2-31. Axial slot antenna on top of main module without solar panels. Top view.

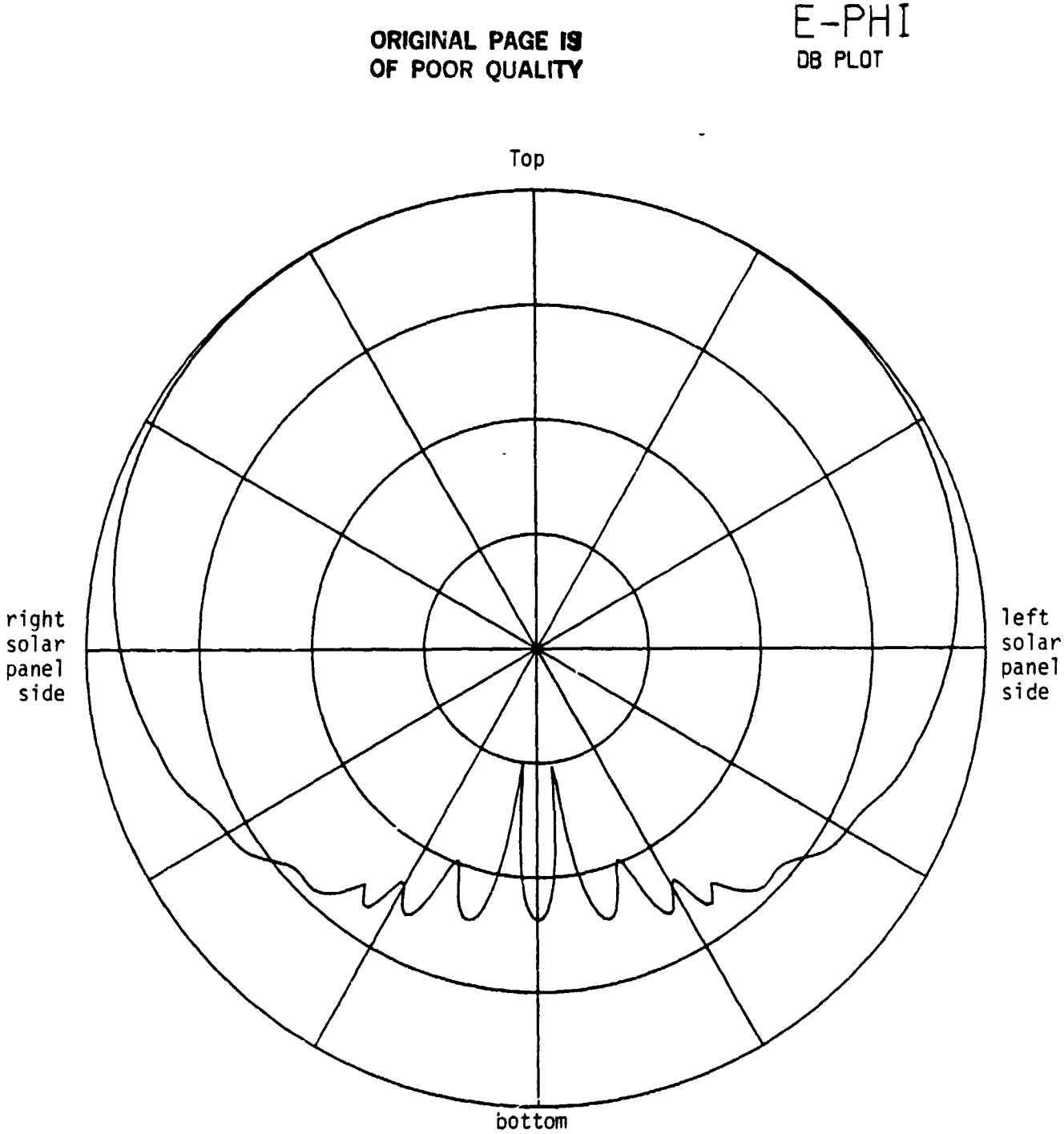


Figure III.2-32. Principal roll plane pattern at .26 GHZ. Axial slot antenna on top of main module without solar panels.

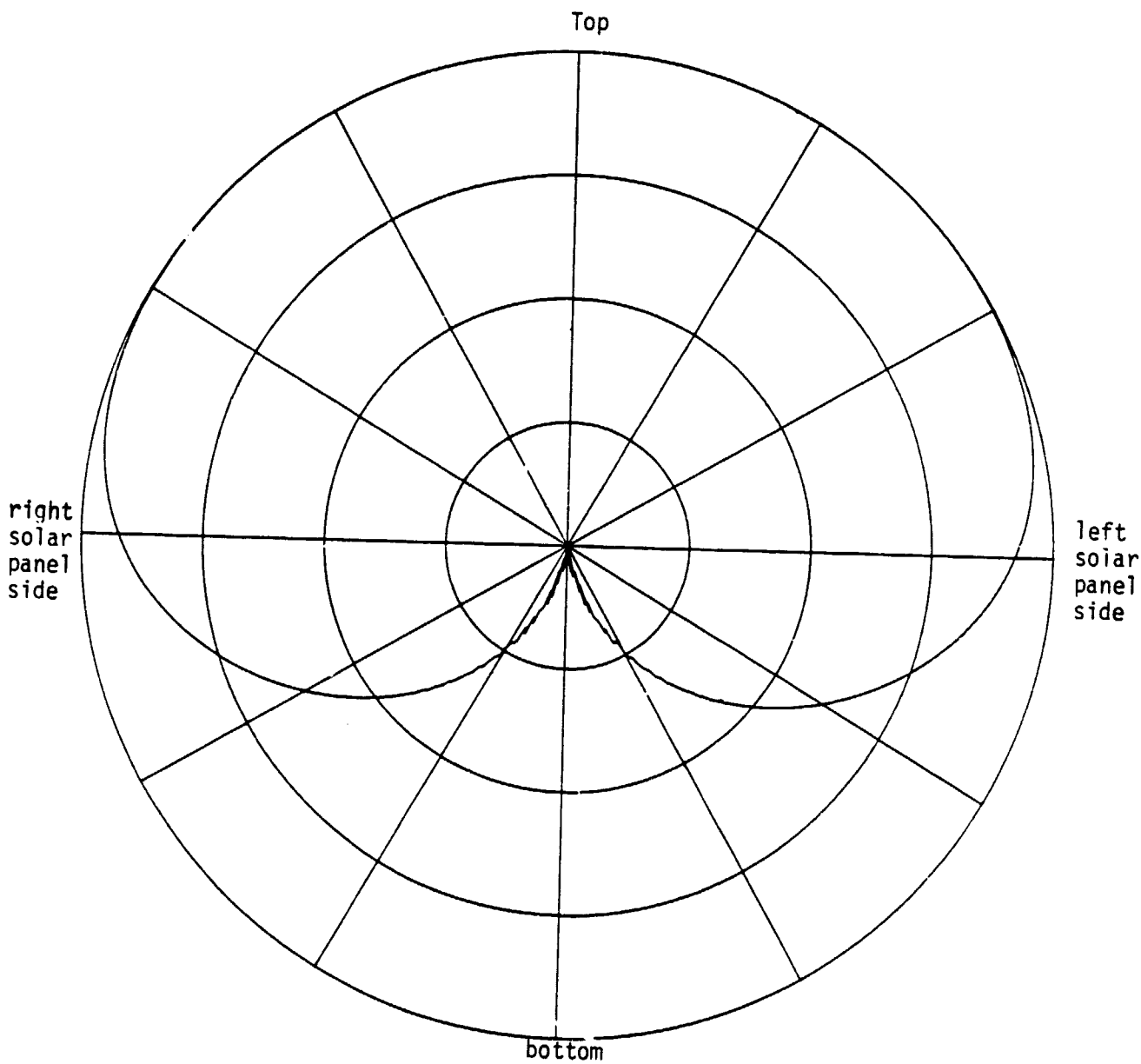


Figure III.2-33. Principal roll plane pattern at 2.2 GHZ. Axial slot antenna on top of main module without solar panels.

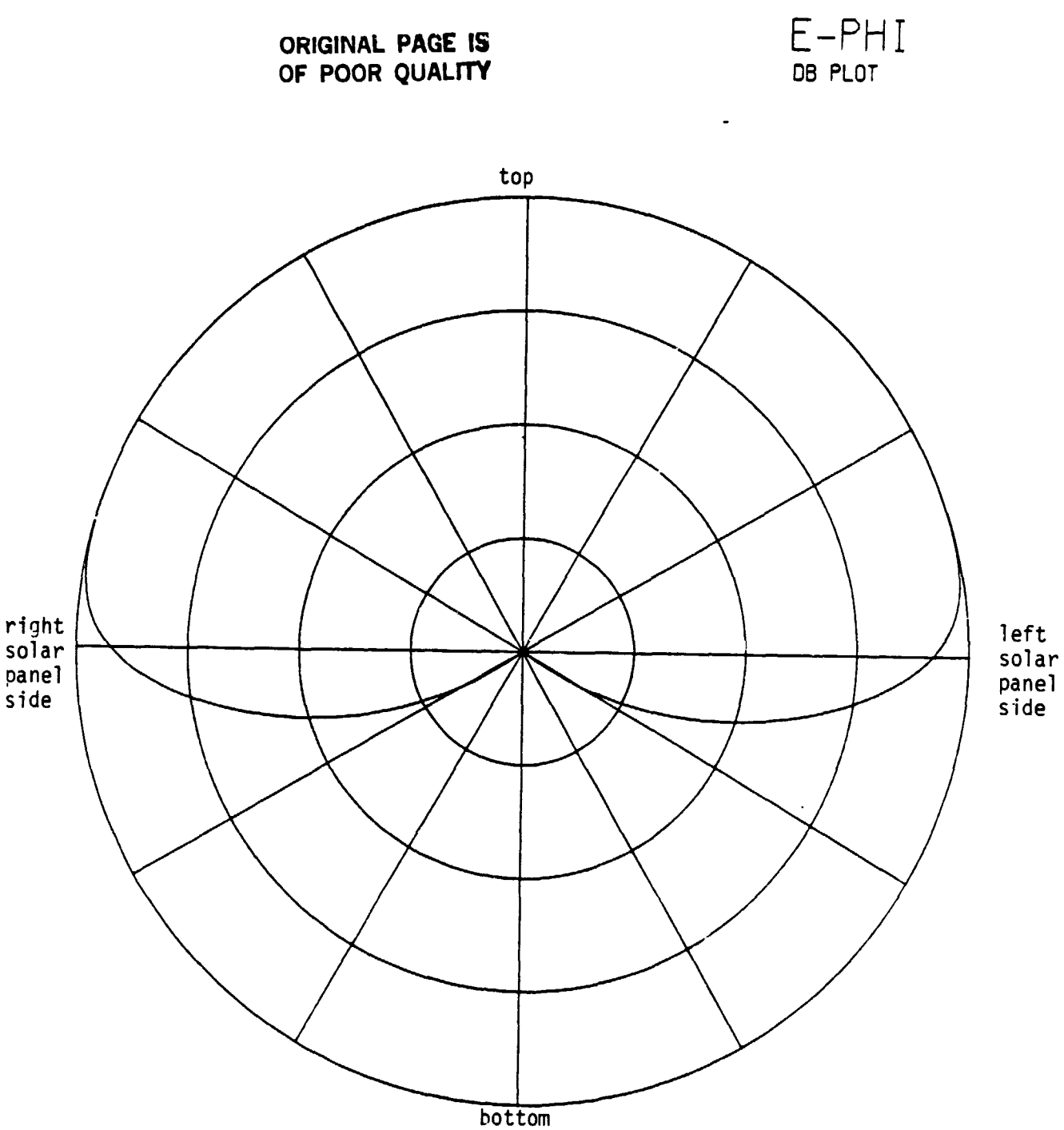
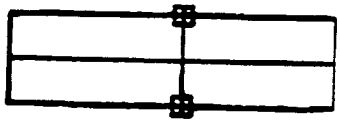


Figure III.2-34. Principal roll plane pattern at 25 GHZ. Axial slot antenna on top of main module without solar panels.

MAIN MODULE OF THE SPACE STATION.
FUSELAGE PROFILE
(ELEVATION PLANE)



S. F. = 200.000

Figure III.2-35. Two axial slot antennas on the top and the bottom of main module without solar panels. Side view.

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MAIN MODULE OF THE SPACE STATION.
CROSS SECTION
(ROLL PLANE)

S. F. = 200.000

Figure III.2-36. Two axial slot antennas on the top and the bottom of main module without solar panels. Front view.

MAIN MODULE OF THE SPACE STATION.
MERIDIAN PROFILE
(AZIMUTH PLANE)

S. F. = 288.000

Figure III.2-37. Two axial slot antennas on the top and the bottom of main module without solar panels. Top view.

E-PHI
DB PLOT

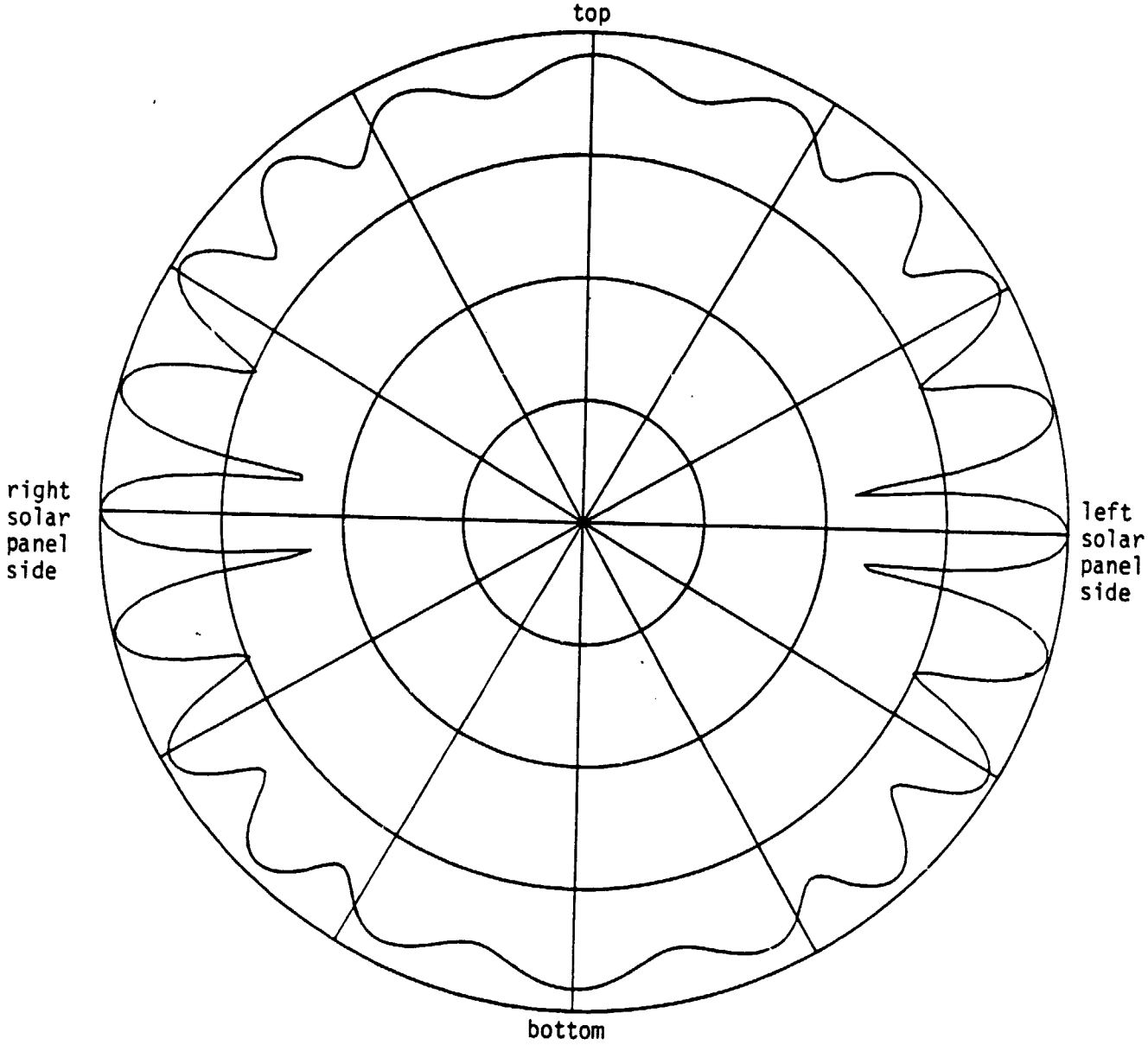


Figure III.2-38. Principal roll plane pattern at .26 GHZ. Two axial slot antennas on the top and the bottom of main module without solar panels.

E-PHI
DB PLOT

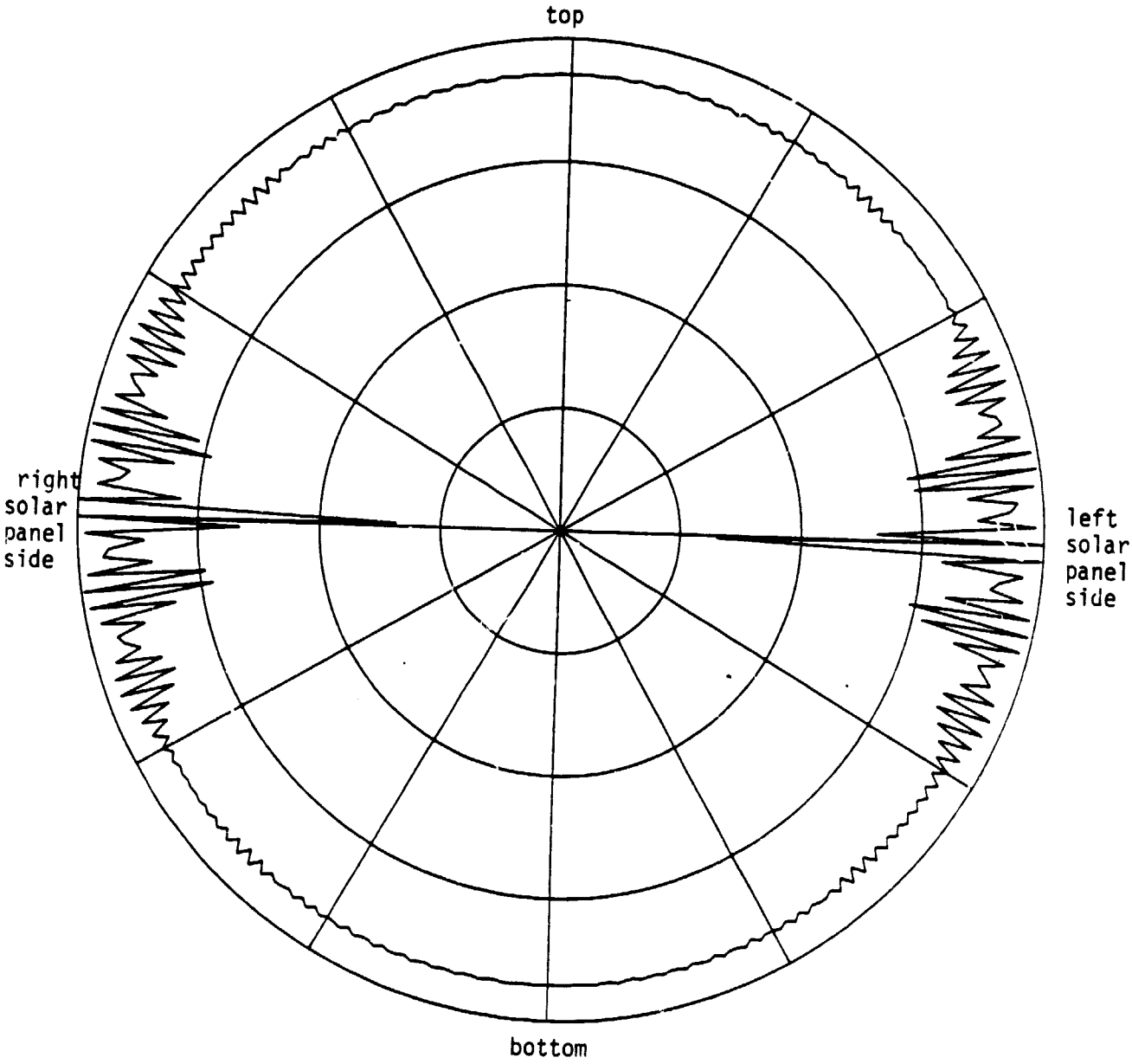


Figure III.2-39. Principal roll plane pattern at 2.2 GHZ. Two axial slot antenna of main module without solar panels.

E-PHI
DB PLOT

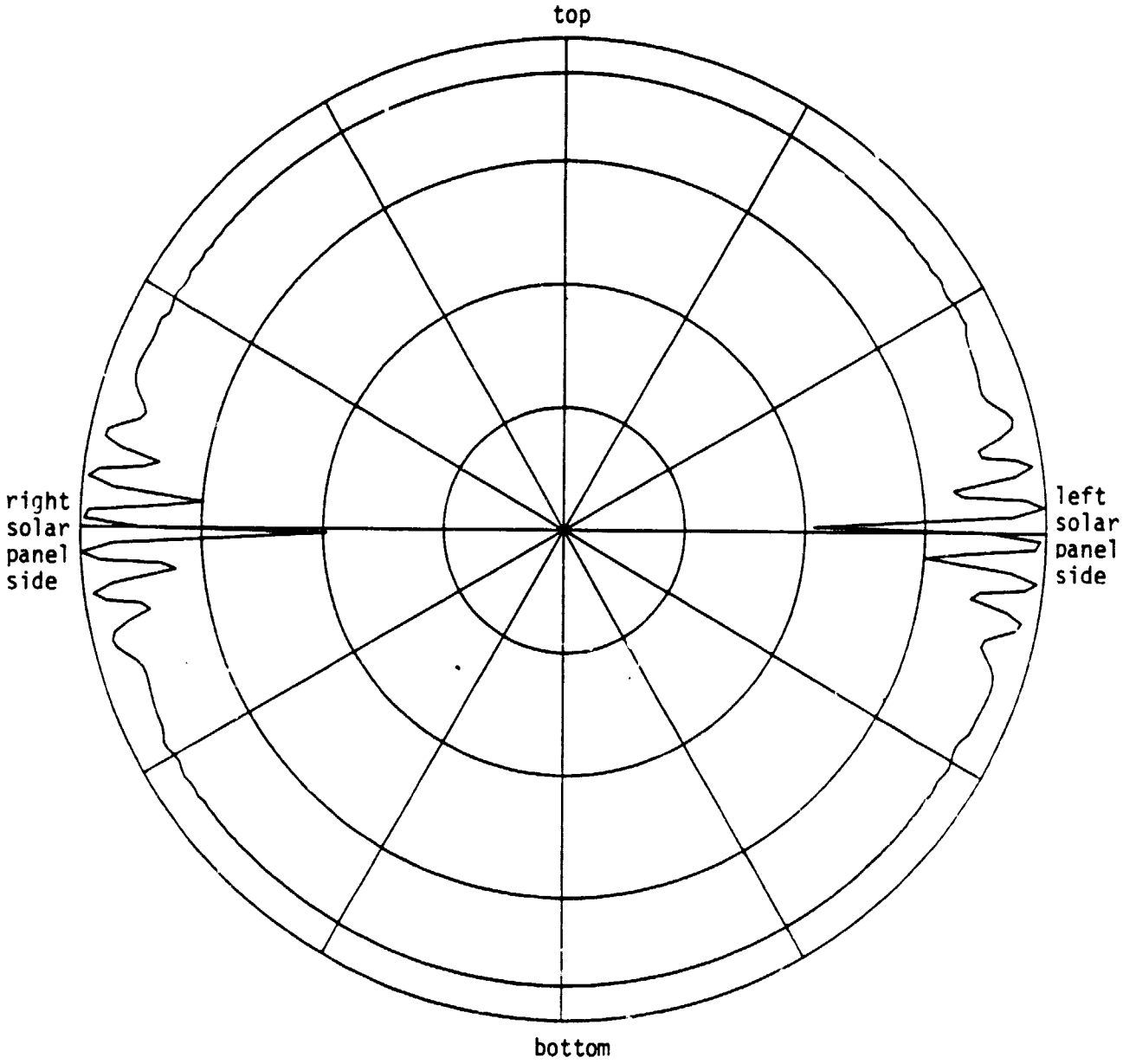
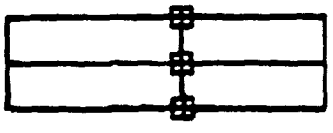


Figure III.2-40. Principal roll plane pattern at 25 GHZ. Two axial slot antennas on the top and the bottom of main module without solar panels.

MAIN MODULE OF THE SPACE STATION.
MODULE PROFILE
(ELEVATION PLANE)



S. F. = 288.000

Figure III.2-41. Four axial slot antennas around main module without solar panels. Side view.

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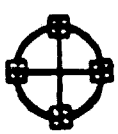
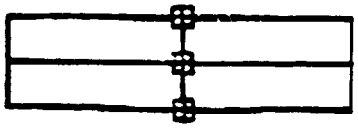
MAIN MODULE OF THE SPACE STATION.
CROSS SECTION
(ROLL PLANE)



S. F. = 288.000

Figure III.2-42. Four axial slot antennas around main module without solar panels. Front view.

MAIN MODULE OF THE SPACE STATION.
RADIATION PROFILE
(AZIMUTH PLANE)



S. F. = 200.000

Figure III.2-43. Four axial slot antennas around main module without solar panels. Top view.

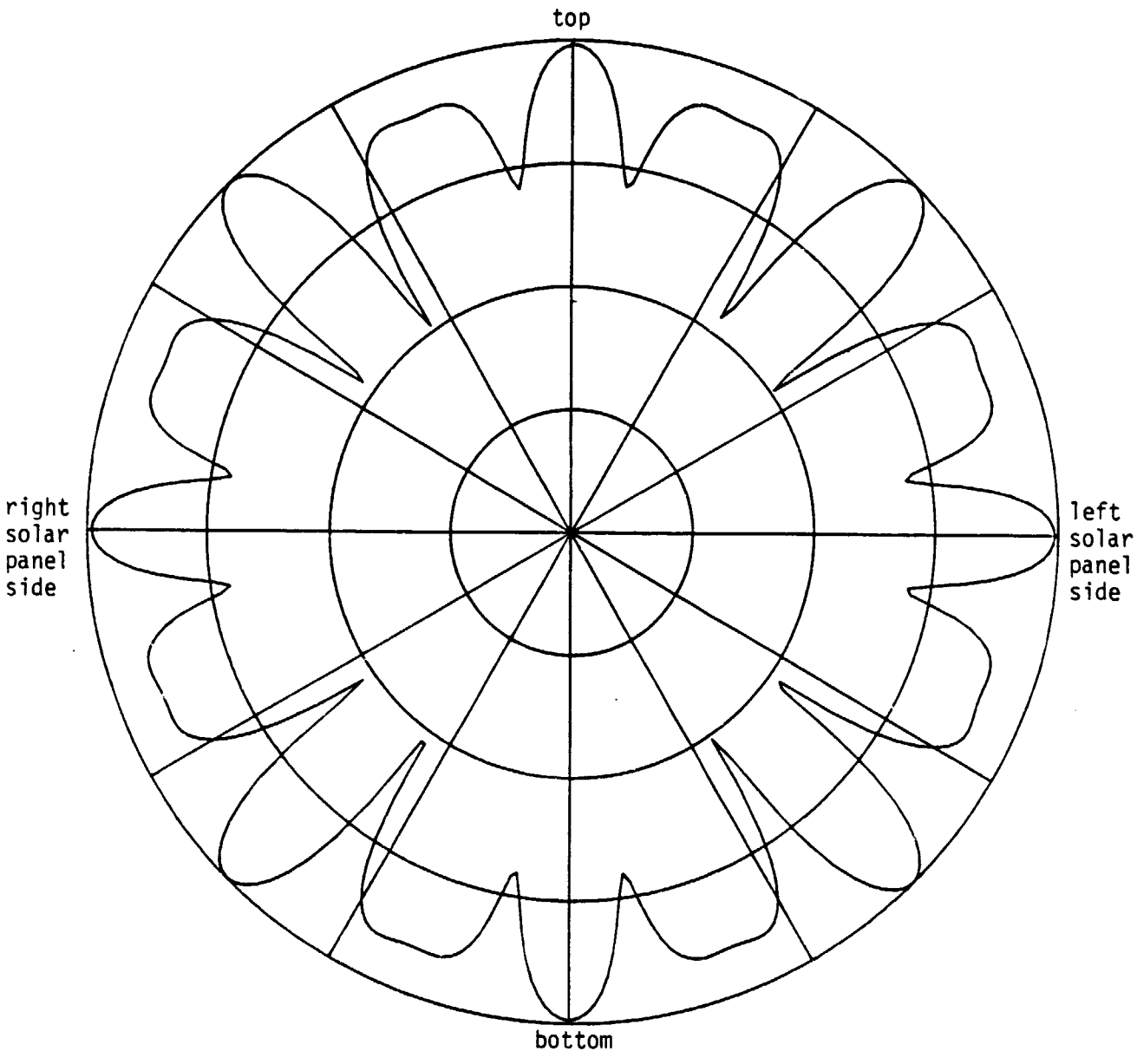


Figure III.2-44. Principal roll plane pattern at .26 GHZ. Four axial slot antennas around main module without solar panels.

E-PHI
DB PLOT

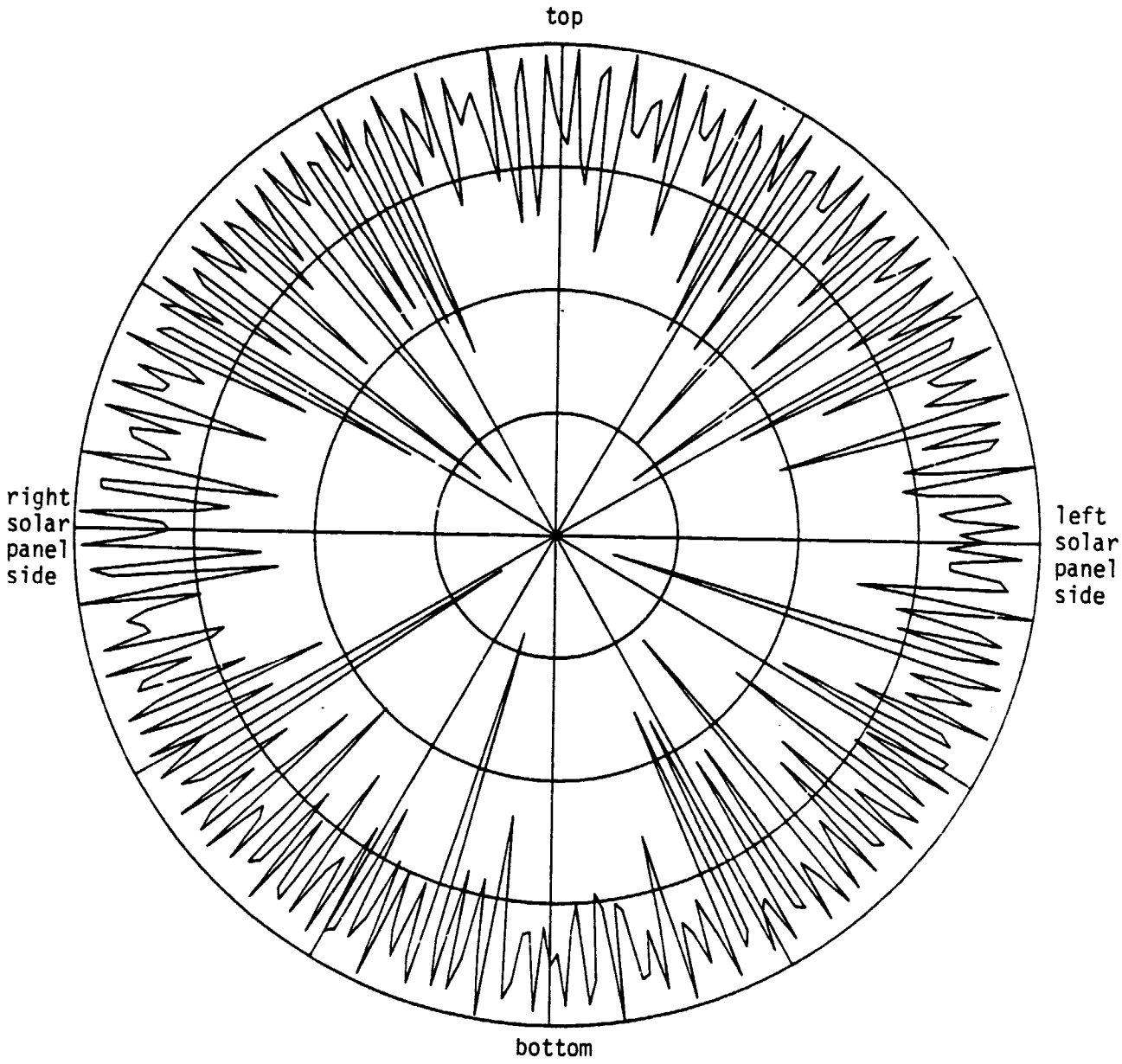


Figure III.2-45. Principal roll plane pattern at 2.2 GHZ. Four axial slot antennas around main module without solar panels.

E-PHI
DB PLOT

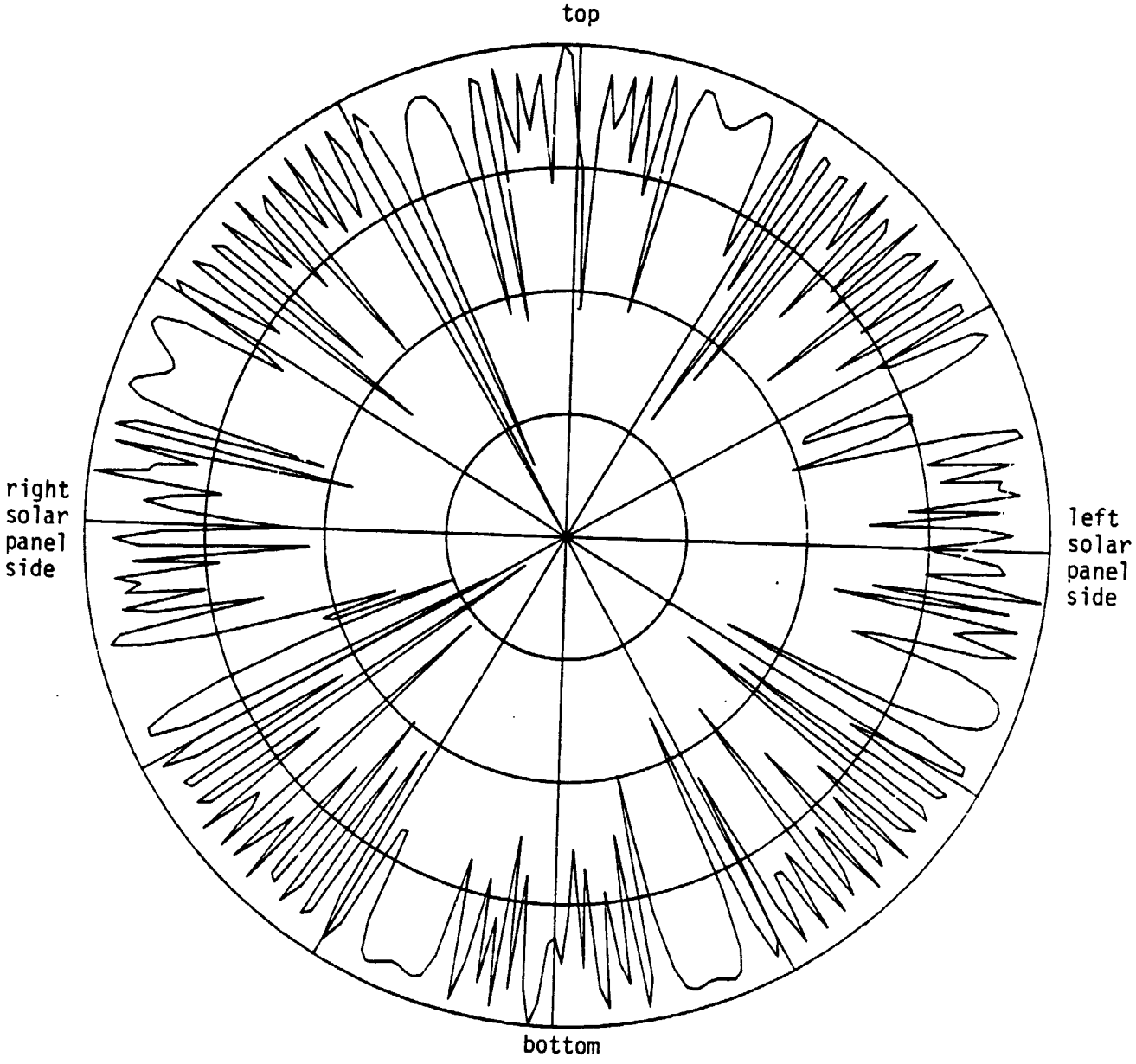


Figure III.2-46. Principal roll plane pattern at 25 GHZ. Four axial slot antennas around main module without solar panels.

```
FQ·MAIN MODULE WITH SOLAR PANELS.
 84.0 1763.5 1763.5
 0. 0. 0.
FC·
 T T
 270.0 -270.0
PG·LEFT SOLAR PANEL
 4 F
 0. 720. -360.
 0. 4320. -360.
 0. 4320. 360.
 0. 720. 360.
PG·RIGHT SOLAR PANEL
 4 F
 0. -720. 360.
 0. -4320. 360.
 0. -4320. -360.
 0. -720. -360.
SG·
 0. 0.
 1
 0. 0.
 .01 5 0. 0. 1
 1. 0.
FQ· .26 GHZ
 1 .26 1.
PP·
 3.75 3
PD·ROLL PLANE
 0. 90.
 90 91 2
 0 360 1
 T 50000
 F 3
EX·
FQ·2.2 GHZ
 1 2.2 1.
EX·
FQ·25. GHZ
 1 25. 1.
EX·
END OF FILE
?? E
SOL1    IS A LOCAL FILE
/
```

Figure III.2-47. Mathematical model input data for main module with two long solar panels.

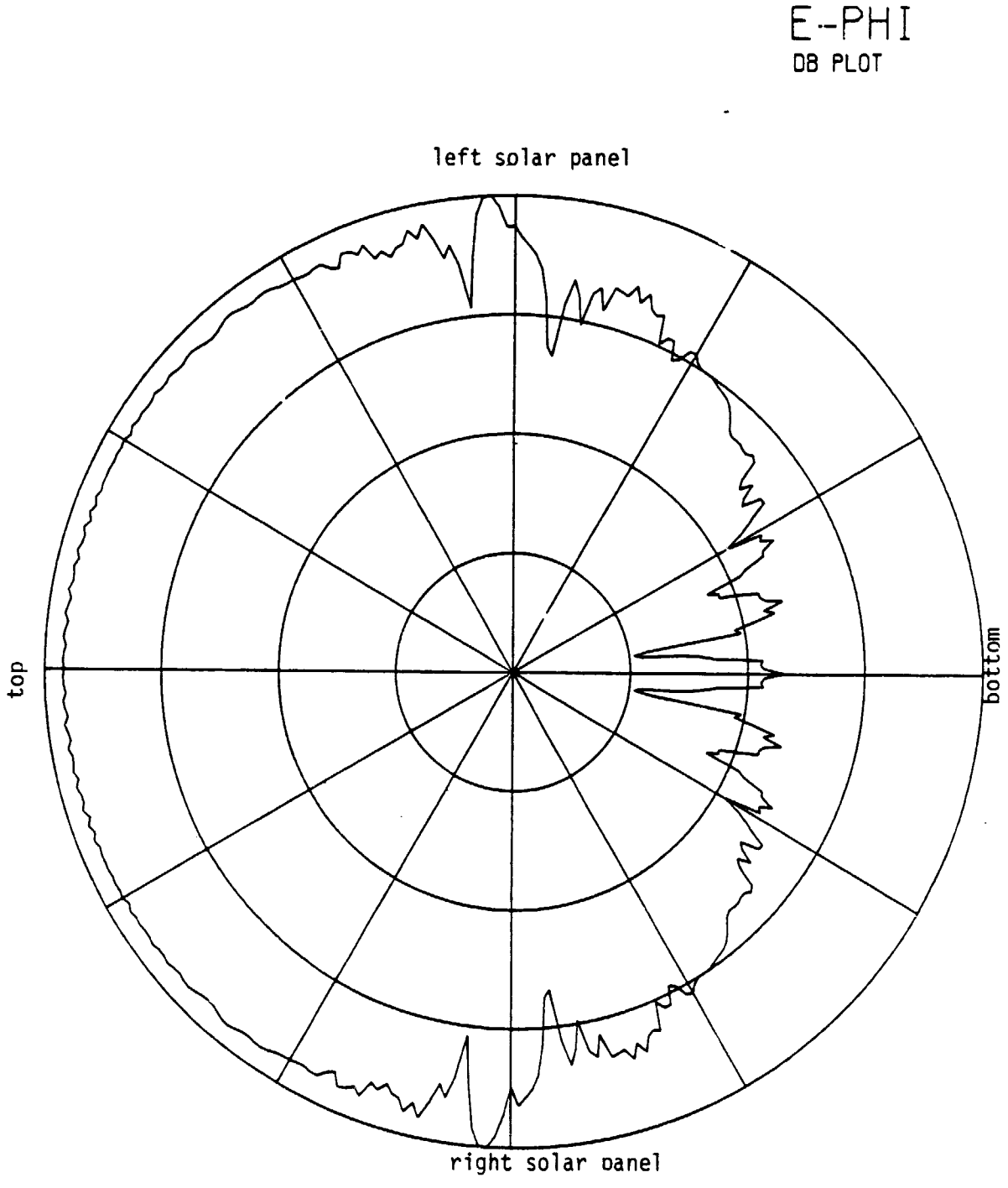


Figure III.2-48. Principal roll plane pattern at .26 GHZ. Axial slot antenna on top of main module with two long solar panels.

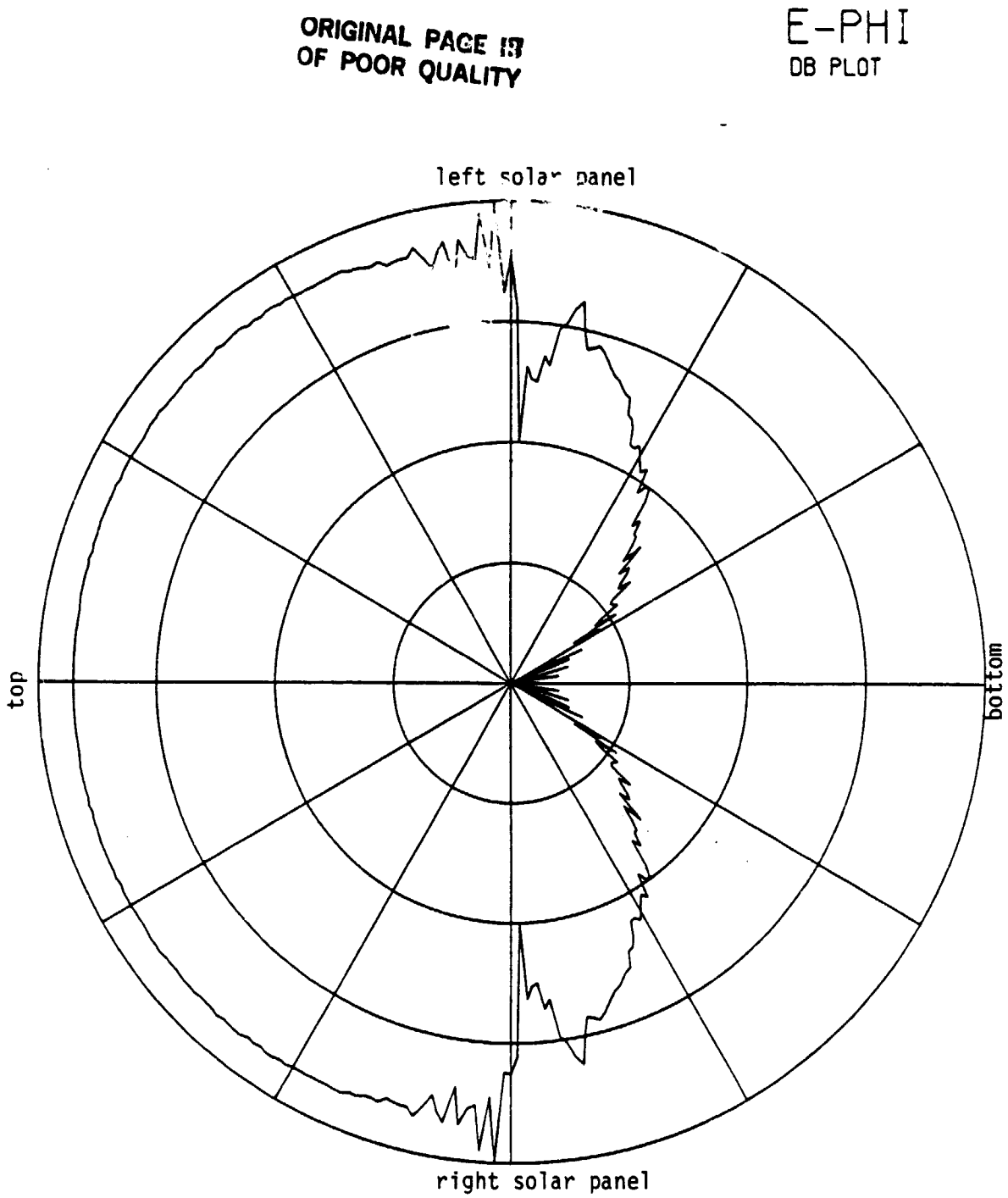


Figure III.2-49. Principal roll plane pattern at 2.2 GHZ. Axial slot antenna on top of main module with two long solar panels.

E-PHI
DB PLOT

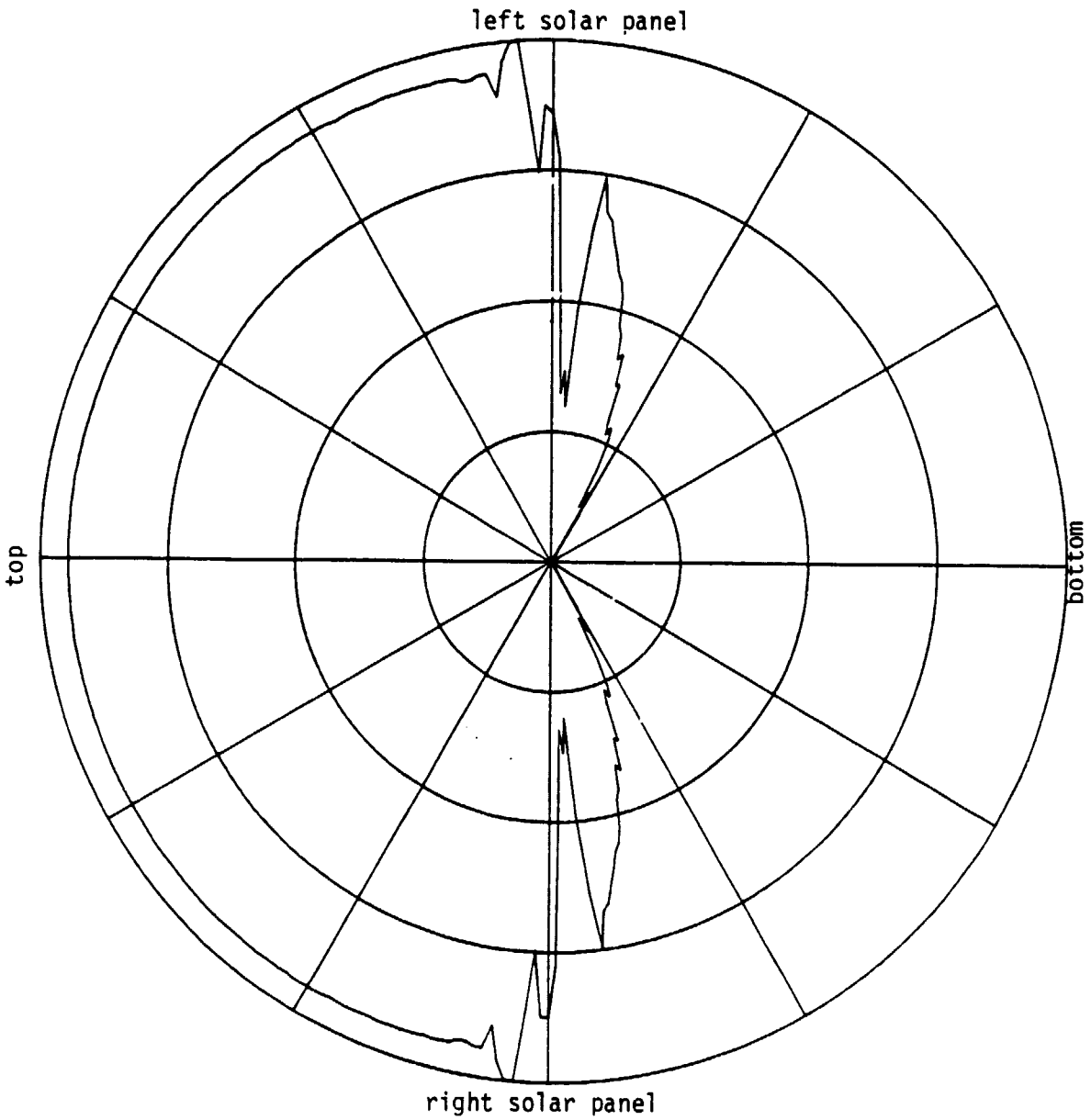
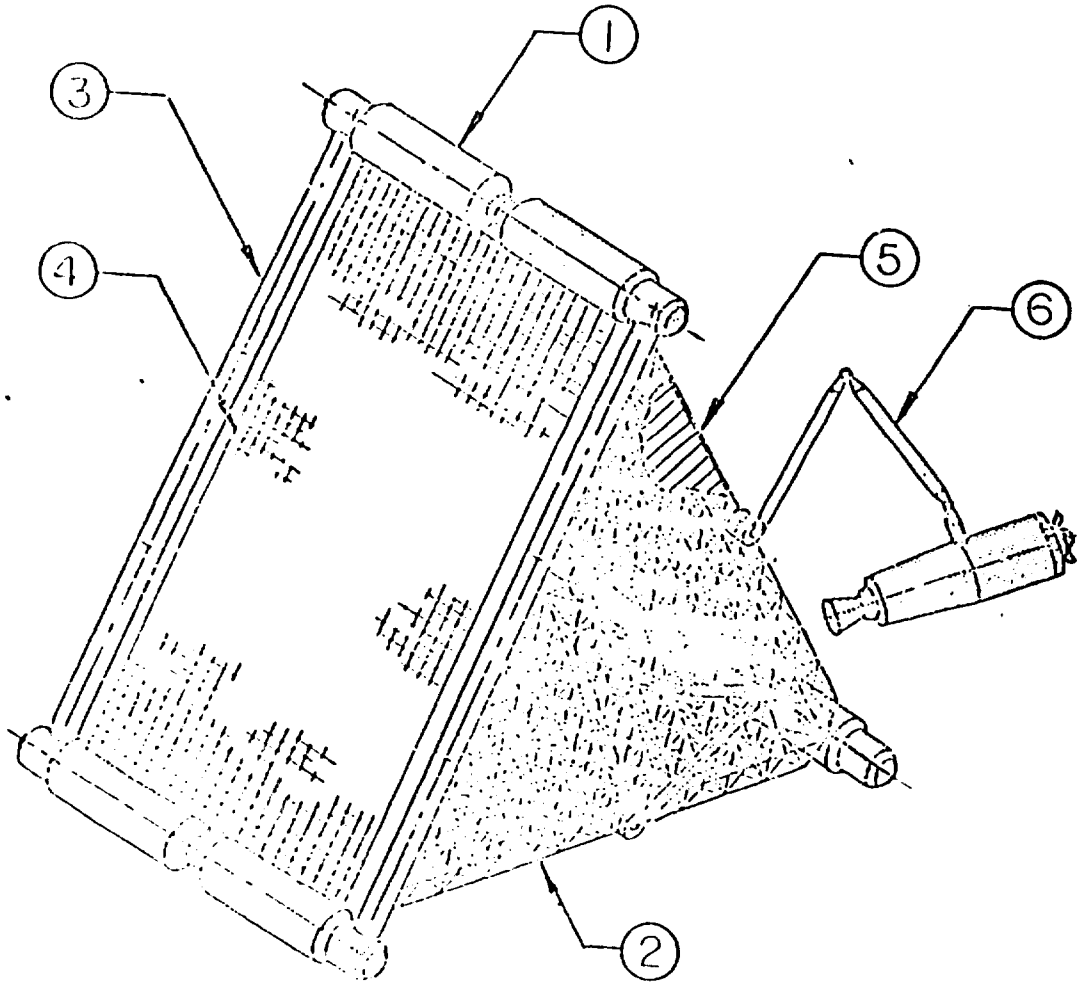


Figure III.2-50. Principal roll plane pattern at 25 GHZ. Axial slot antenna on top of main module with two long solar panels.



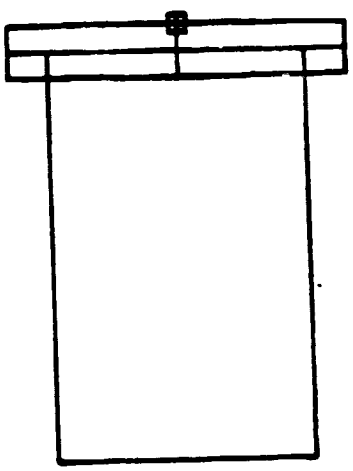
1. SIX MODULES
   (14 FT. DIA. X 46 FT LONG
   - 0 TWO HABITAT
   - 0 TWO SERVICE
   - 0 LOGISTICS
   - 0 LABORATORY
2. THREE TRUSS PLATFORMS
   (125 FT X 70 FT X 8 FT)
3. THREE CONNECTING TUNNELS
4. SOLAR CELLS ATTACHED TO TRUSS
5. RADIATOR PANEL
6. MANIPULATOR (2)

Figure III.3-1. Design of second space station.

```
FQ·SPACE21
 84.0 1763.5 1763.5
 0. 0. 0.
PP·
 3.75 3
FC·
 T T
 552.0 -552.0
PG·LEFT SOLAR PANEL
 4 T
 0. 84. -420.
 -1299.6 834. -420.
 -1299.6 834. 420.
 0. 84. 420
PG·RIGHT SOLAR PANEL
 4 T
 0. -84. 420.
 -1299.6 -834. 420.
 -1299.6 -834. -420.
 0. -84. -420.
SQ·
 0. 0.
 1
 0. 0.
  .01 .5 0. 0. 1
 1. 0.
FQ·.26 GIGAHERTZ
 1 .26 1.
PD·ROLL PLANE
 0. 0.
 90 91 2
 0 360 1
 T 50000
 F 3
EX·
FQ·2.2 GIGAHERTZ
 1 2.2 1.
EX·
FQ·25 GIGAHERTZ
 1 25 1.
EX·
END OF FILE
?? E
SPACE21 IS A LOCAL FILE
/
```

Figure III.3-2. Mathematical model input data for main module with two diagonal solar panels.

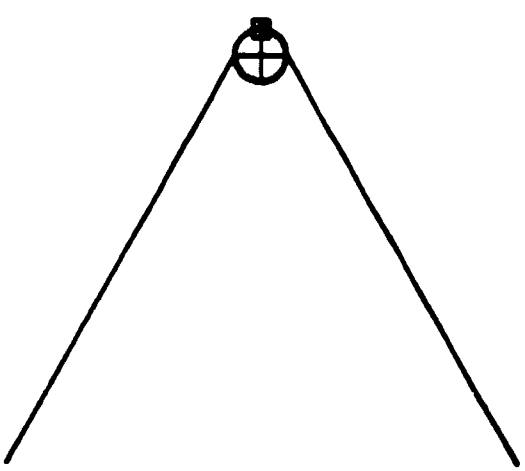
SPACE STATION.
FUSELAGE PROFILE
(ELEVATION PLANE)



S. F. = 200.000

Figure III.3-3. Axial slot antenna on top of main module with two diagonal solar panels. Side view.

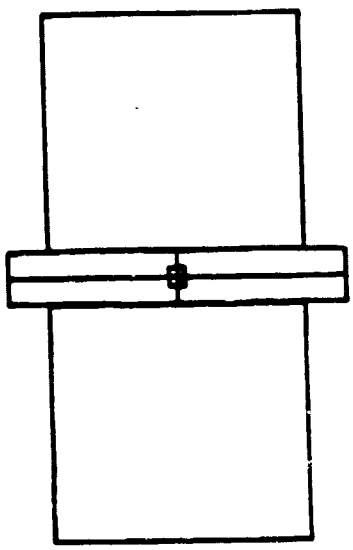
SPACE STATION.
CROSS SECTION
(ROLL PLANE)



S. F. = 200.000

Figure III.3-4. Axial slot antenna on top of main module with two diagonal solar panels. Front view.

SPACE STATION.
HERDING PROFILE
(AZIMUTH PLANE)



S. F. = 200.000

Figure III.3-5. Axial slot antenna on top of main module with two diagonal solar panels. Top view.

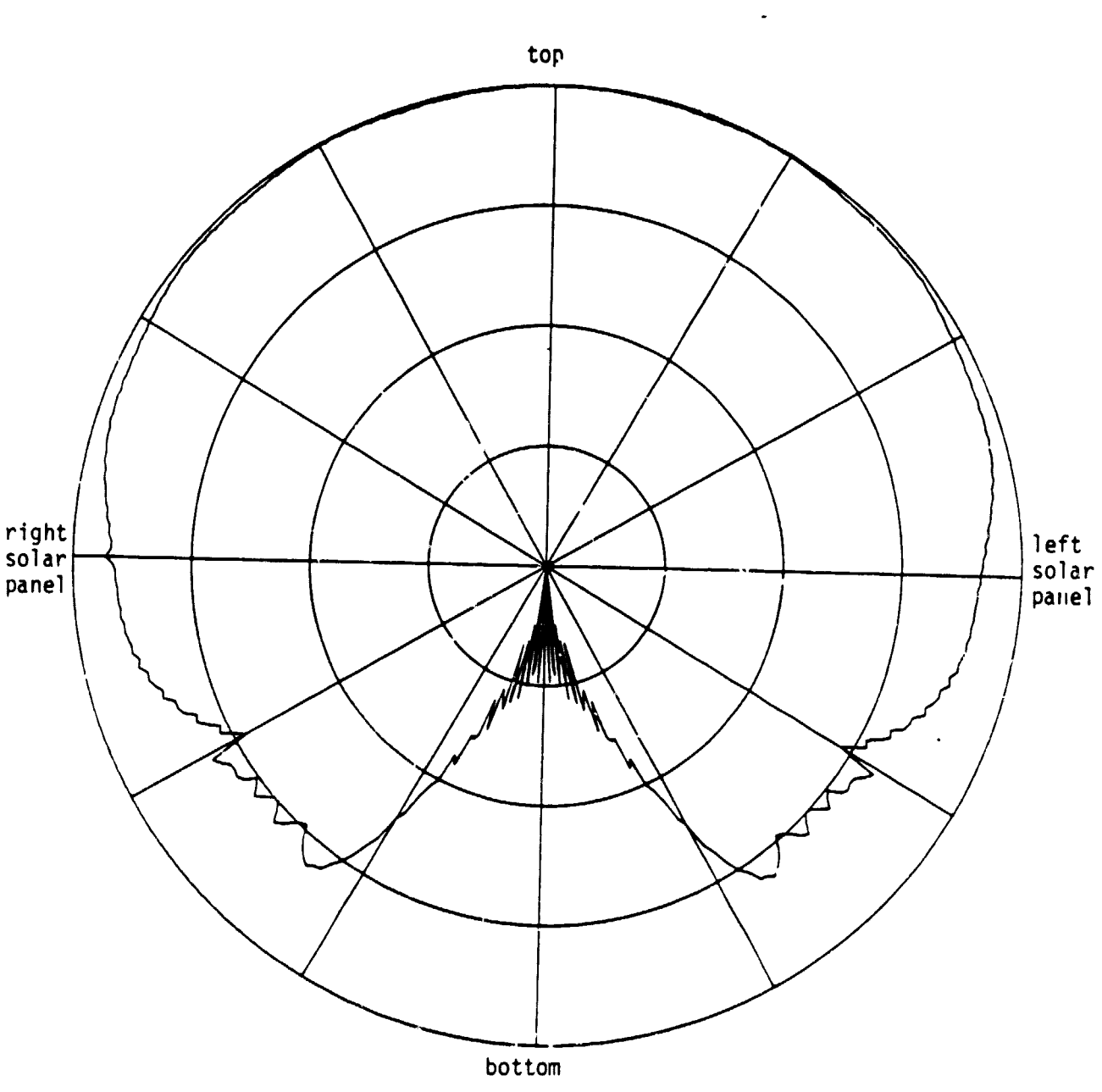


Figure III.3-6. Principal roll plane pattern at .26 GHZ. Axial slot antenna on top of main module with two diagonal solar panels.

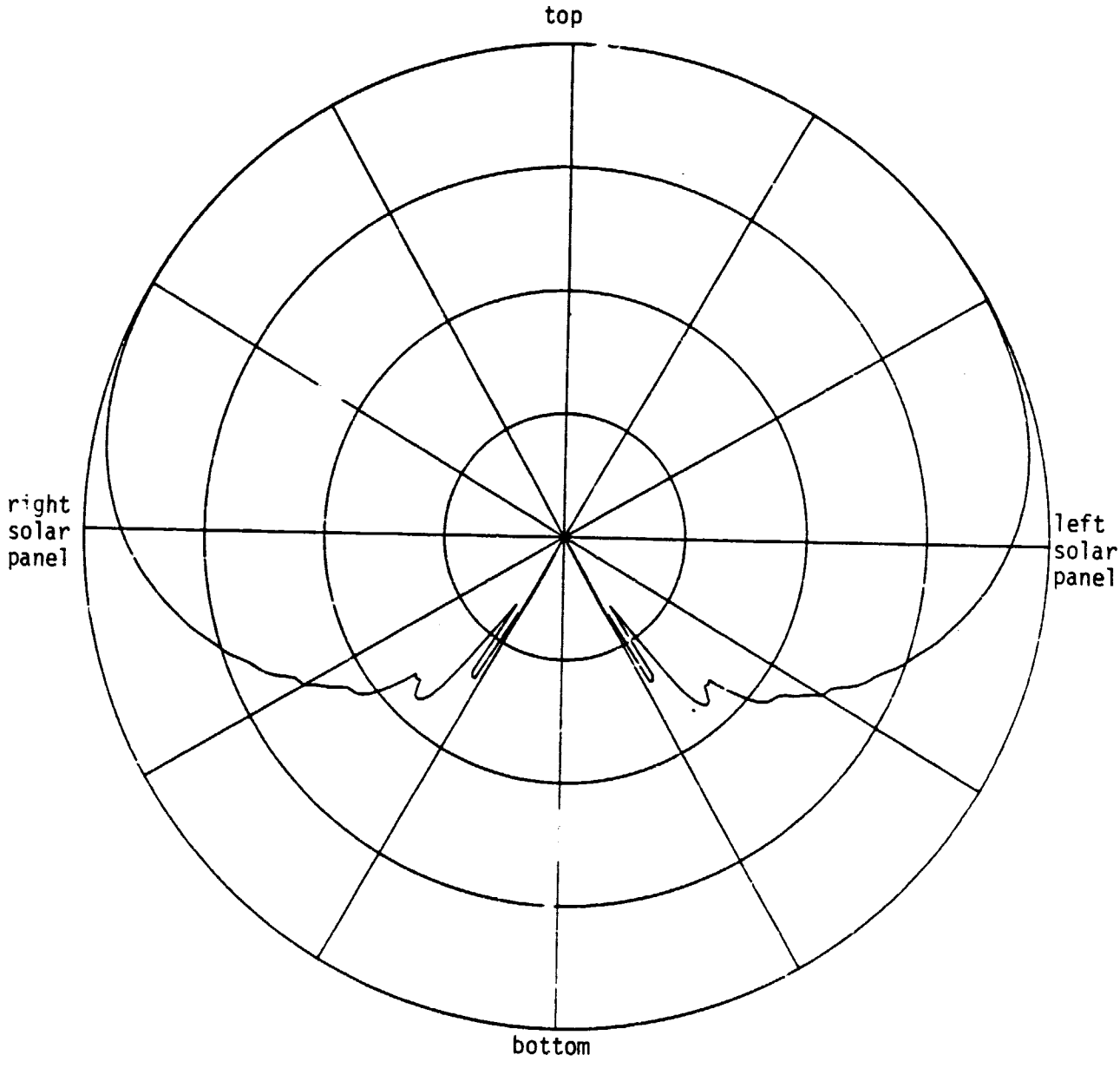


Figure III.3-7. Principal roll plane pattern at 2.2 GHZ. Axial slot antenna on top of main module with two diagonal solar panels.

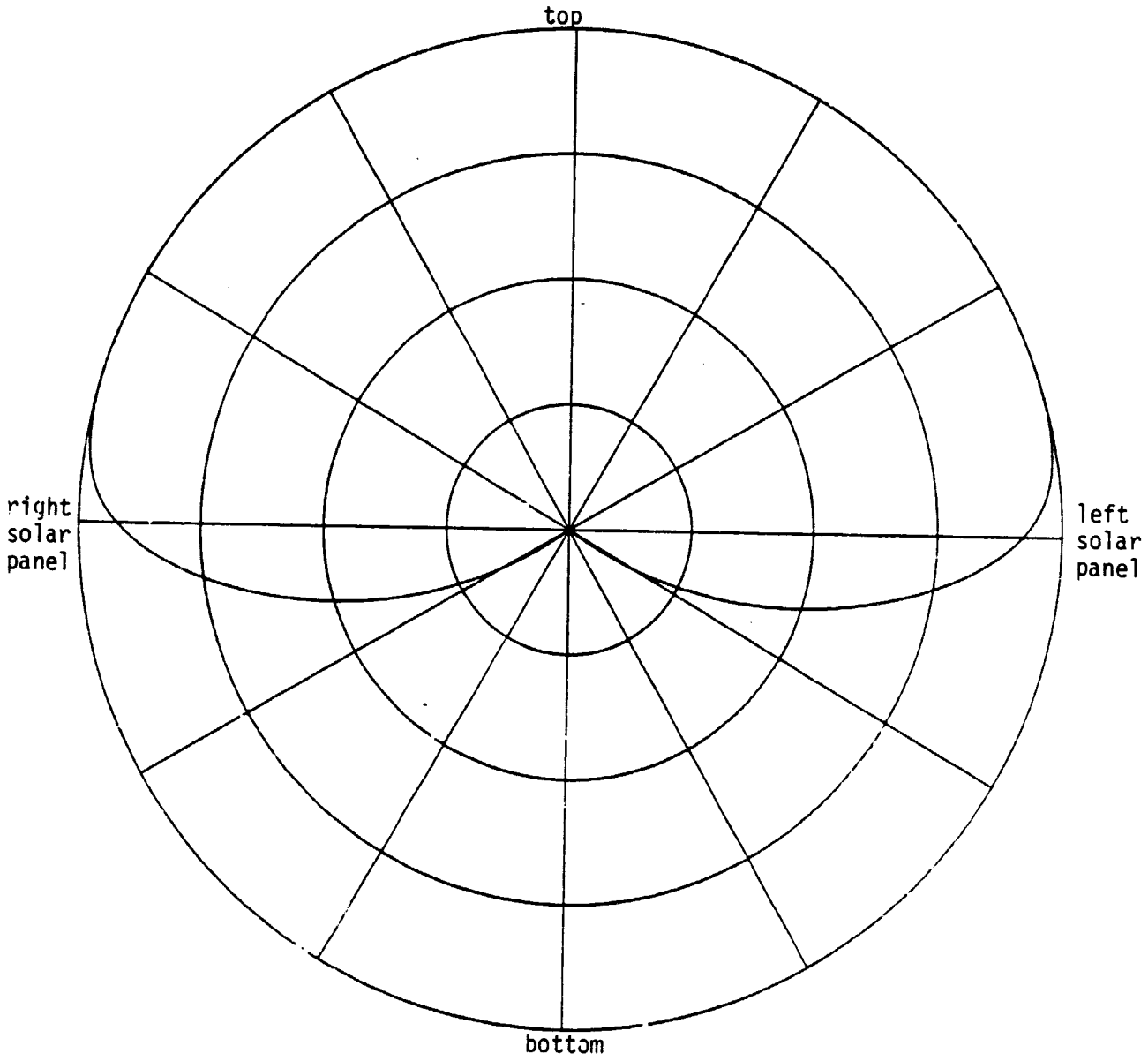
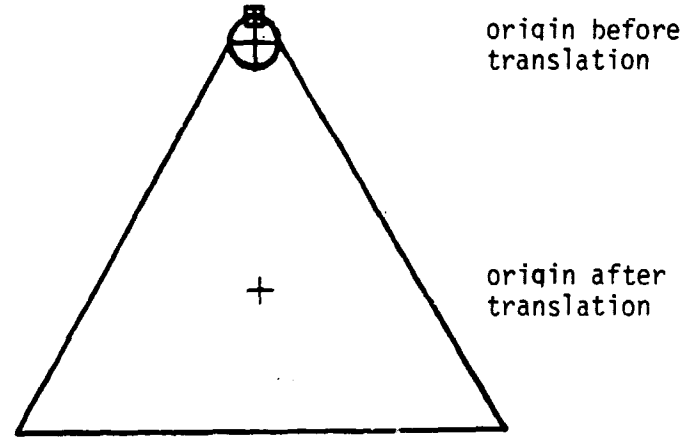


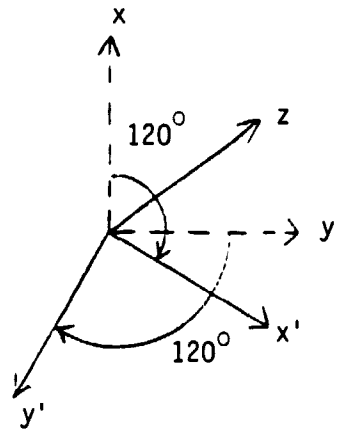
Figure III.3-8. Principal roll plane pattern at 25 GHZ. Axial slot antenna on top of main module with two diagonal solar panels.

MAIN MODULE.SOLAR PANELS .BOTTOM TRUSS PLATFORM.
CROSS SECTION
(ROLL PLANE)

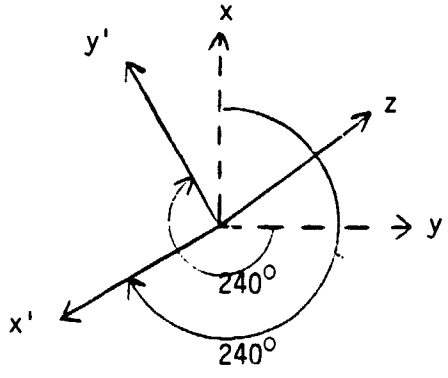


S. F. = 200.000

Figure III.3-9. Origin of coordinate axis before and after translation.



A- Coordinate axis x' and y' after 120° rotation around z axis, used for simulation of right module.



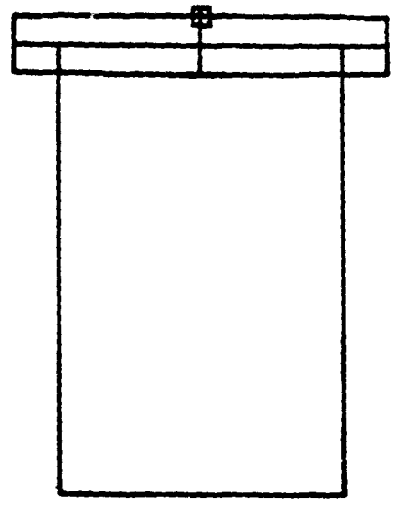
B. Coordinate axis x' and y' after 240° rotation around z axis, used for simulation of left module.

Figure III.3-10. Coordinate axis before and after rotation around z axis after translation of origin.

```
FG SPACE27
 84.0 1763 5 1763.5
 0. 0. 0.
PP
 3.75 3
FC
 T T
 552 0 -552 0
PG LEFT SOLAR PANEL
 4 T
 0. 84. -420.
 -1299.6 834. -420.
 -1299.6 834. 420.
 0. 84. 420.
PG RIGHT SOLAR PANEL
 4 T
 0. -84. 420.
 -1299.6 -834. 420.
 -1299.6 -834. -420.
 0. -84. -420.
PG BOTTOM TRUSS PLATFORM
 4 F
 -1299.6 834. 420.
 -1299.6 834. -420.
 -1299.6 -834. -420.
 -1299.6 -834. 420.
SG
 0. 0.
 1
 0. 0.
 .01 .5 0. 0. 1
 1. 0.
FQ .26 GIGAHERTZ
 1 .26 1.
PD ROLL PLANE
 0. 0.
 90 91 2
 0 360 1
 T 50000
 F 3
EX
SG
 -45. 0.
 1
 0. 0.
 .01 .5 0. 0. 1
 1. 0.
SP
 T 1. 0.
RT
 -649.8 0. 0.
 0. 0. 90. 0.
PD ROLL PLANE
 0. 120.
 90 91 2
 0 360 1
 T 50000
 F 3
EX
END OF FILE
?? E
SPACE27 IS A LOCAL FILE
/
```

Figure III.3-11. Mathematical model input data for main module, two diagonal solar panels and bottom truss platform. Two axial slot antennas; one on the main module, the other on the right module.

SPACE27
FUSELAGE PROFILE
(ELEVATION PLANE)



S. F. = 288.000

Figure III.3-12. Axial slot antenna on top of the main module with two diagonal solar panels and bottom truss platform. Side view.

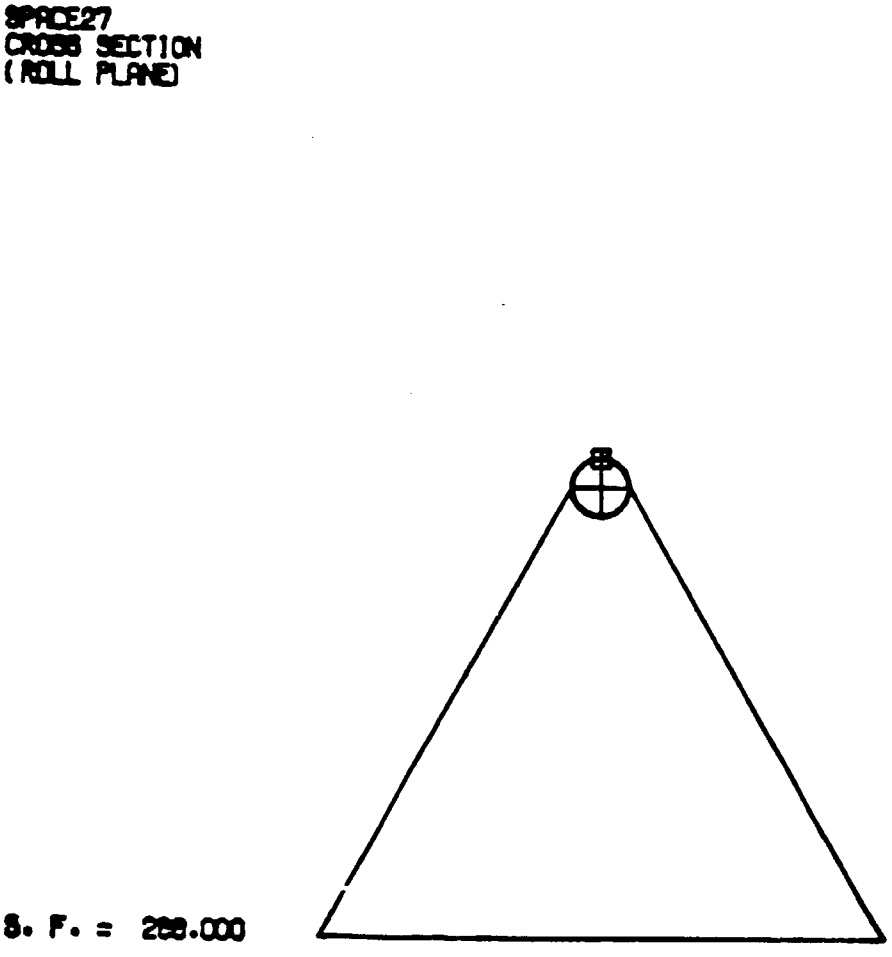
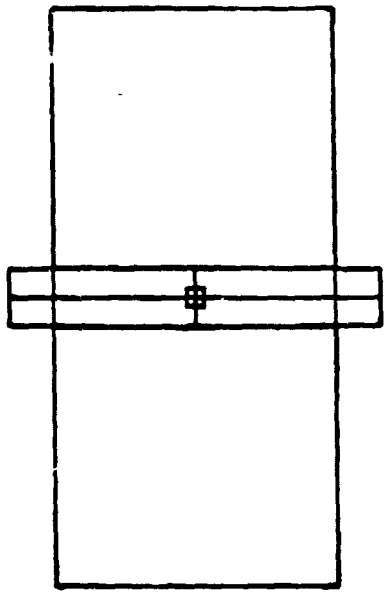


Figure III.3-13. Axial slot antenna on top of the main module with two diagonal solar panels and bottom truss platform. Front view.

SPACE27
HERDING PROFILE
(AZIMUTH PLANE)



S. F. = 200.000

Figure III.3-14. Axial slot antenna on top of the main module with two diagonal solar panels and bottom truss platform. Top view.

E-PHI
DB PLOT

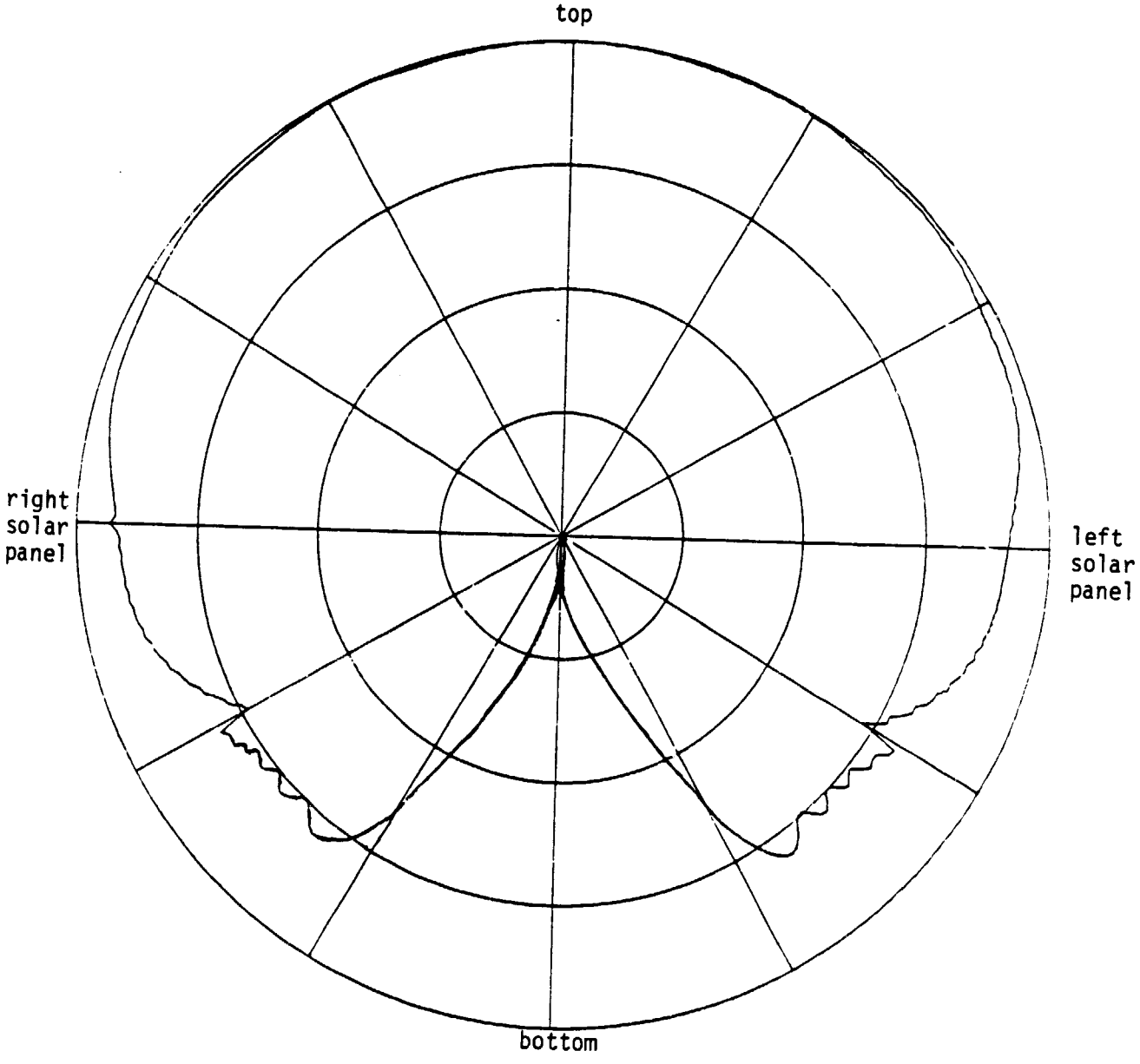


Figure III.3.15. Principal roll plane pattern at .26 GHZ. Axial slot antenna on top of main module with two diagonal solar panels and bottom truss platform.

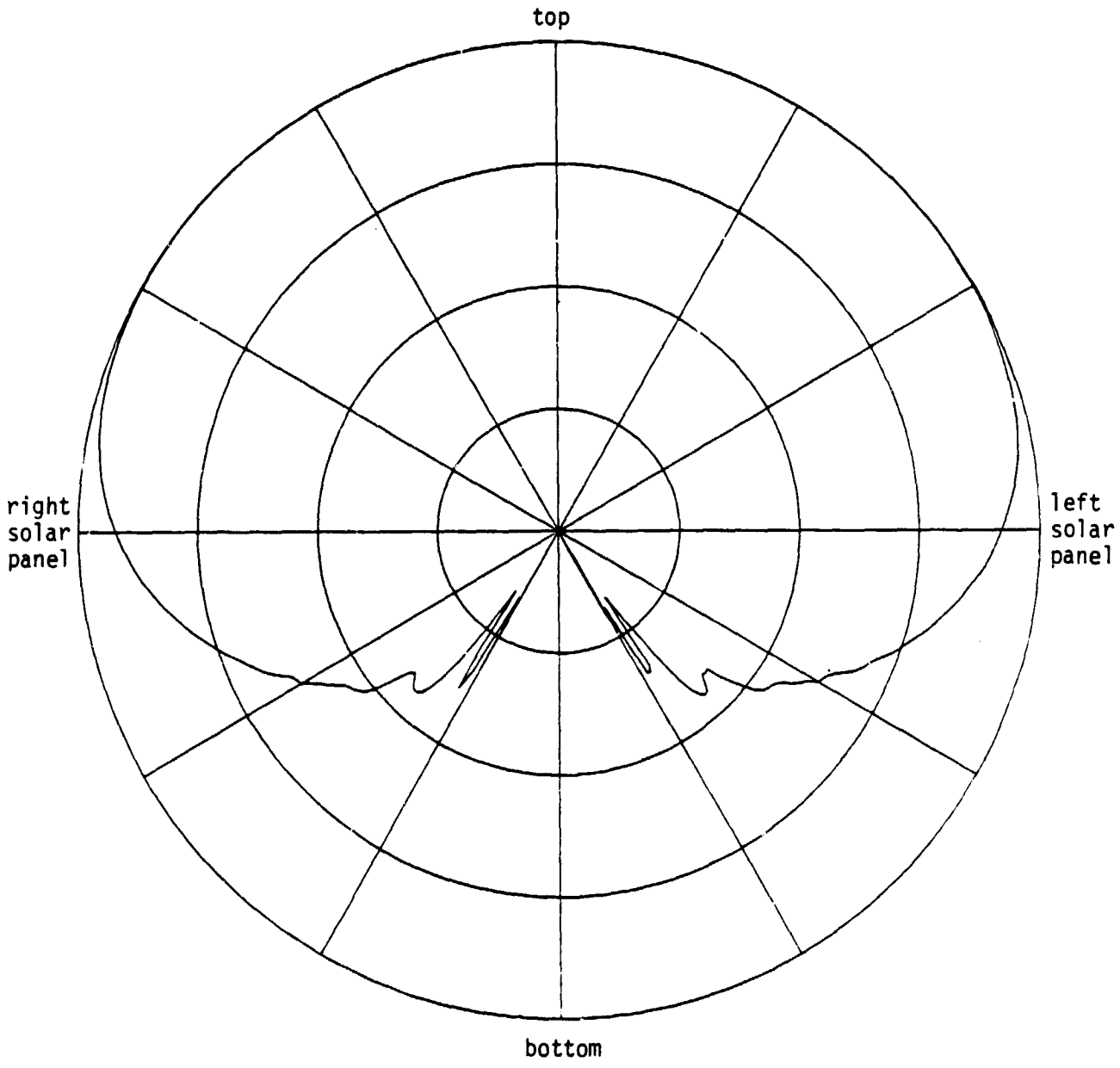


Figure III.3.16. Principal roll plane pattern at 2.2 GHZ. Axial slot antenna on top of main module with two diagonal solar panels and bottom truss platform.

E-PHI
DB PLOT

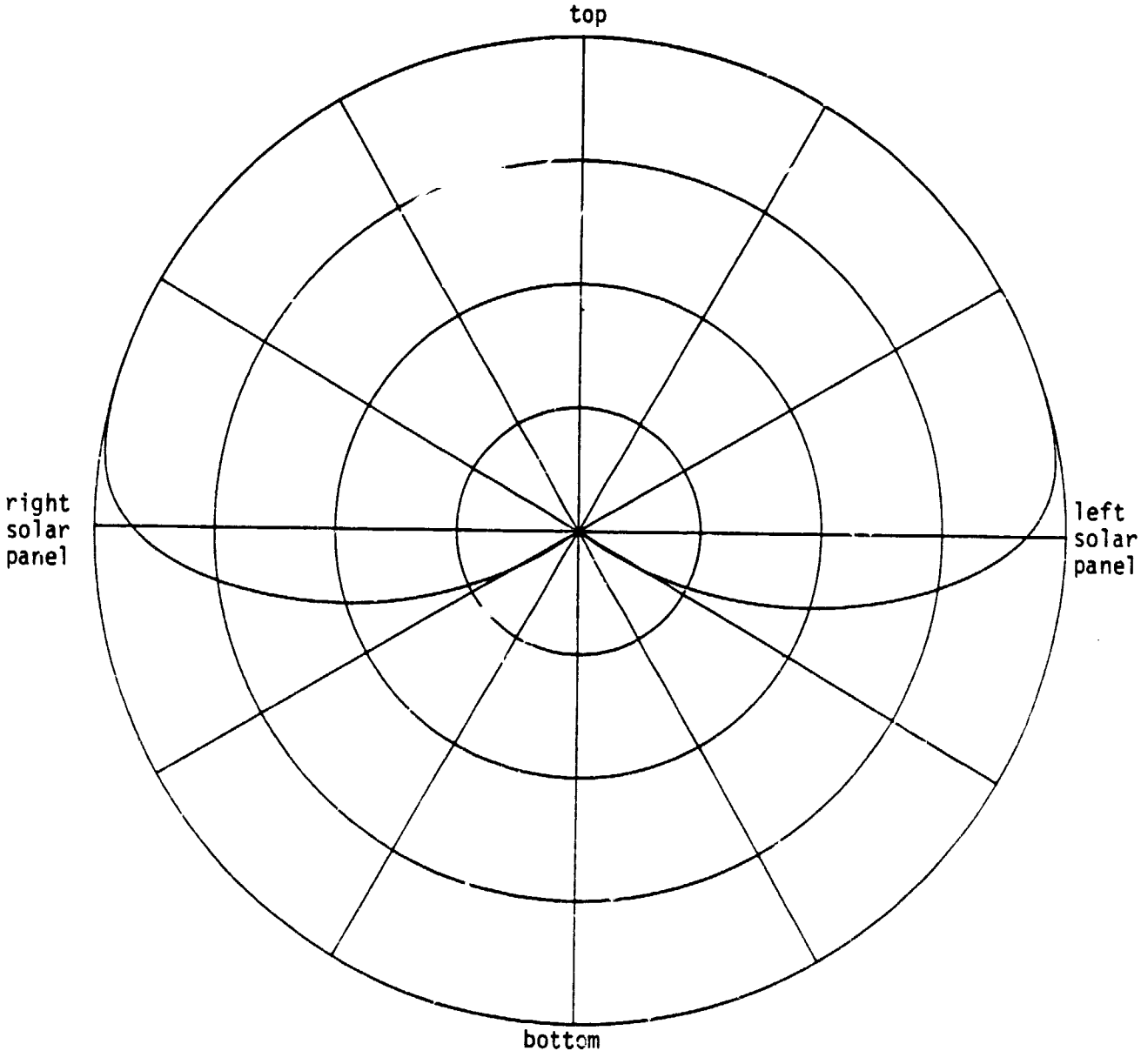
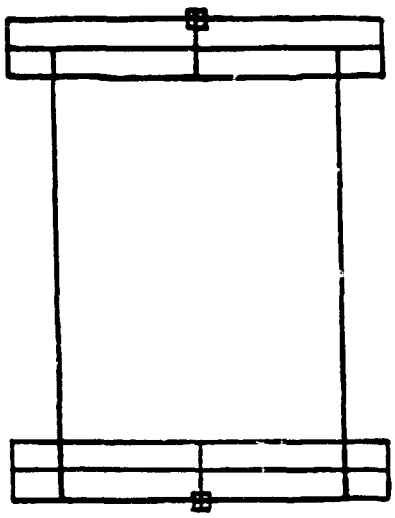


Figure III.3-17. Principal roll plane pattern at 25 GHZ. Axial slot antenna on top of main module with two diagonal solar panels and bottom truss platform.

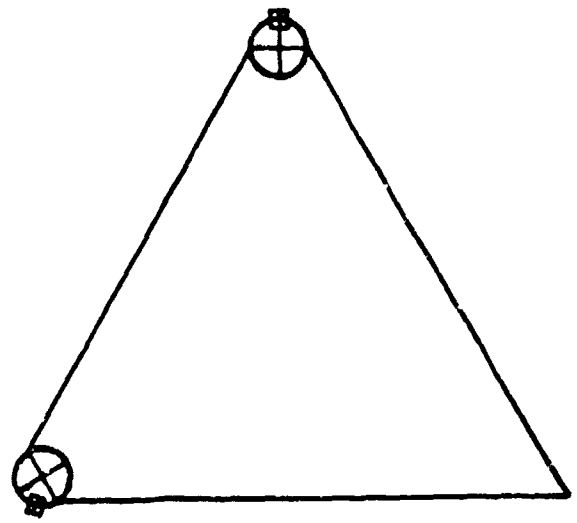
SPACE27
FUSELAGE PROFILE
(ELEVATION PLANE)



S. F. = 200.000

Figure III.3- 8. Two axial slot antennas; one on top of the main module, the other on the right module, with two diagonal solar panels and bottom truss platform Side view.

SPACE27
CROSS SECTION
(ROLL PLANE)

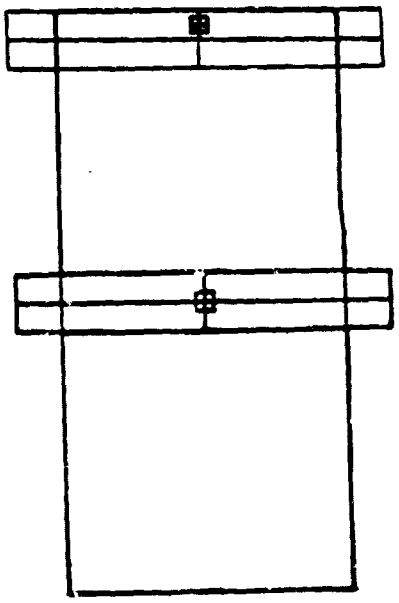


S. F. = 200.000

45°

Figure III.3-19. Two axial slot antennas; one on top of the main module, the other on the right module, with two diagonal solar panels and bottom truss platform. Front view.

SPACE27
HEADING PROFILE
(AZIMUTH PLANE)



S. F. = 200.000

Figure III.3-20. Two axial slot antennas; one on top of the main module, the other on the right module, with two diagonal solar panels and bottom truss platform. Top view.

E-PHI
DB PLOT

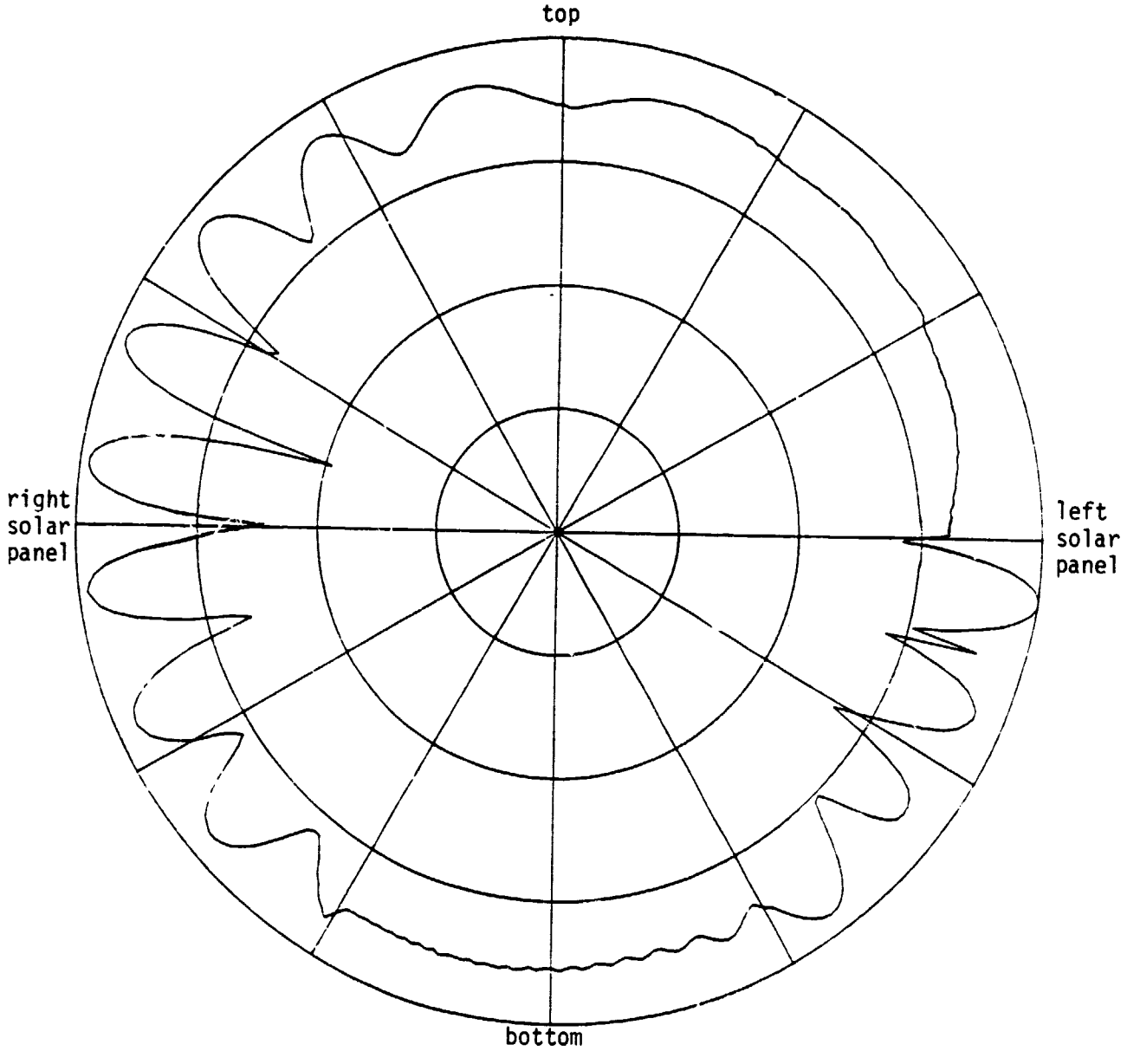


Figure III.3-21. Principal roll plane pattern at .26 GHZ. Two axial slot antenna; one on top of main module, the other on the right module.

C-2

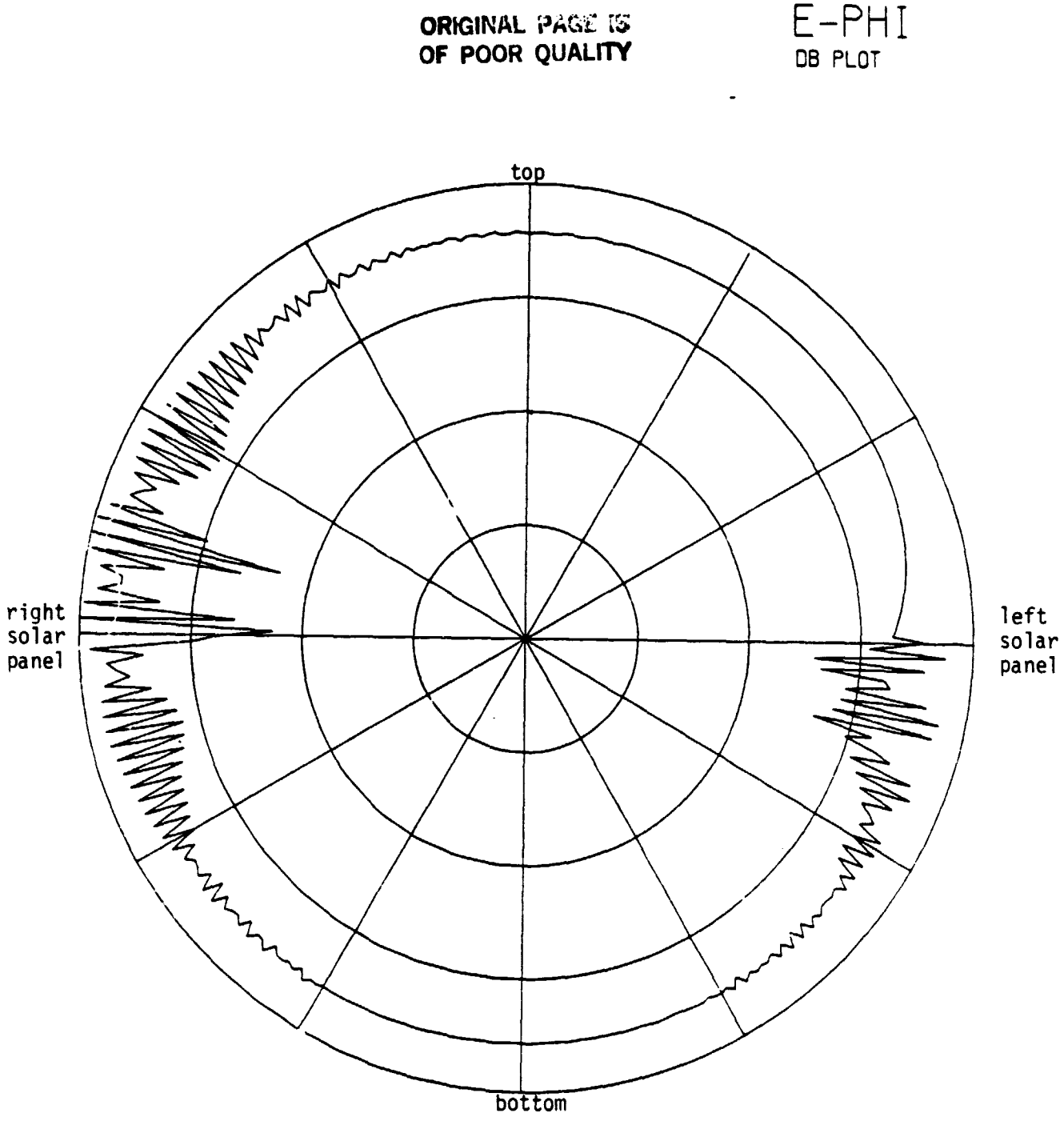


Figure III.3-22. Principal roll plane pattern at 2.2 GHZ. Two axial slot antennas; one on top of main module, the other on the right module.

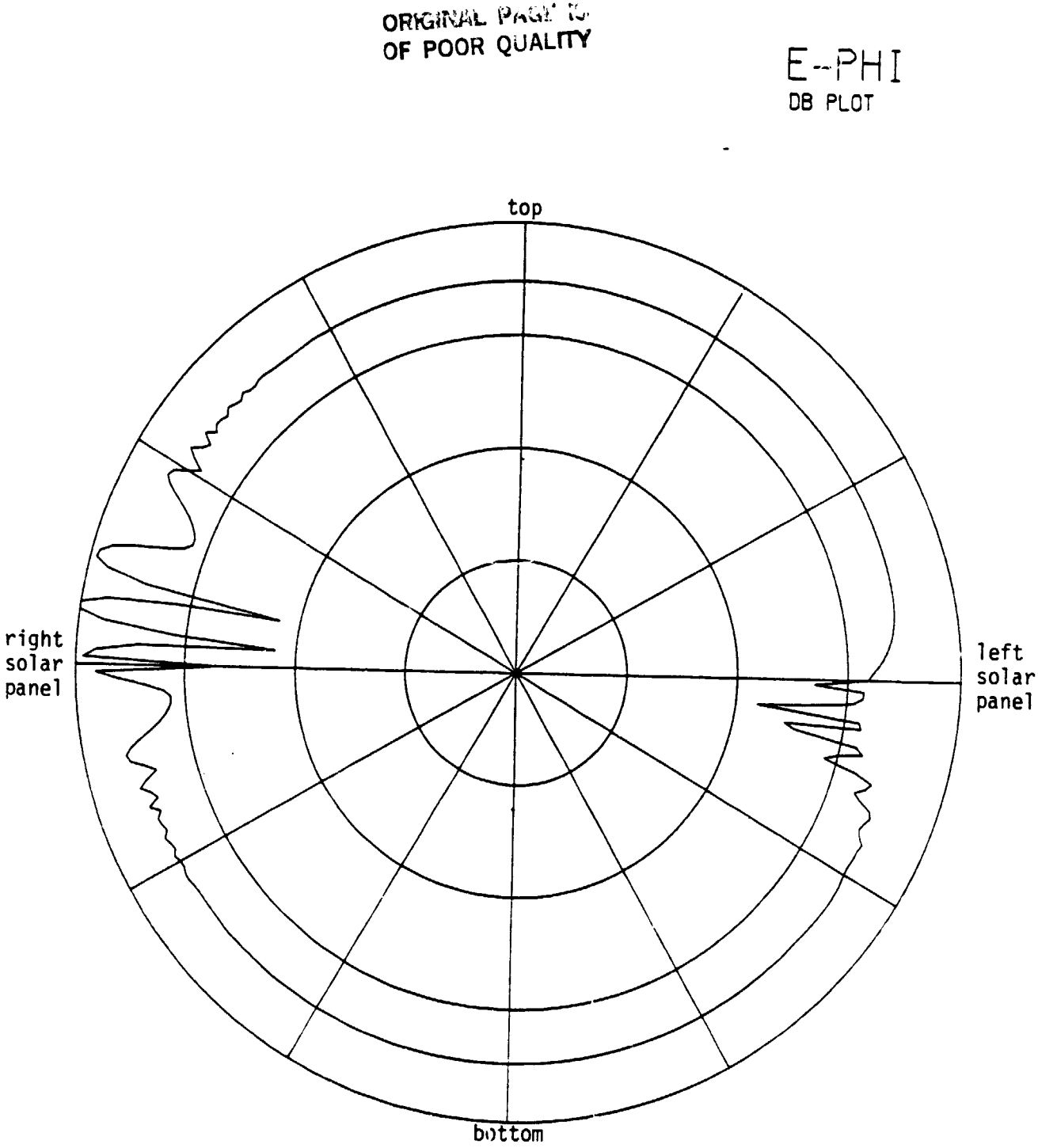
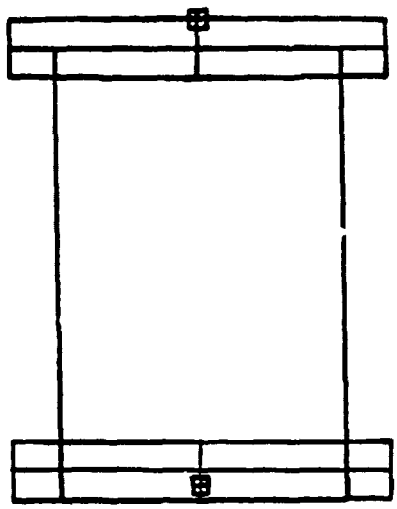


Figure III.3-23. Principal roll plane pattern at 25 GHZ. Two axial slot antennas; one on top of main module, the other on the right module.

```
FG SPACE29
 84.0 1763.5 1763.5
 0. 0. 0.
PP
 3.75 3
FC
 T T
 552.0 -552.0
PG LEFT SOLAR PANEL
 4 T
 0. 84. -420.
 -1299.6 834. -420.
 -1299.6 834. 420.
 0. 84. 420.
PG RIGHT SOLAR PANEL
 4 T
 0. -84. 420.
 -1299.6 -834. 420.
 -1299.6 -834. -420.
 0. -84. -420.
PG BOTTOM TRUSS PLATFORM
 4 F
 -1299.6 834. 420.
 -1299.6 834. -420.
 -1299.6 -834. -420.
 -1299.6 -834. 420.
SQ
 0. 0.
 1
 0. 0.
  .01 5 0 0 1
 1. 0.
FQ .26 GIGAHERTZ
 1 .26 1.
PD ROLL PLANE
 0. 0.
 90 91 2
 0 360 1
 T 50000
 F 3
EX
SP
 T 1. 0.
RT
 -649.8 0. 0.
 0. 0. 90. 0.
PD ROLL PLANE
 0. 119.9
 90 91 2
 0 360 1
 T 50000
 F 3
EX
PD
 0. 239.9
 90 91 2
 0 360 1
 T 50000
 F 3
EX
END OF FILE
?? E
SPACE29 IS A LOCAL FILE
/
```

Figure III.3-24. Mathematical model input data for main module, two diagonal solar panels and bottom truss platform. Three axial slot antennas; one on each module.

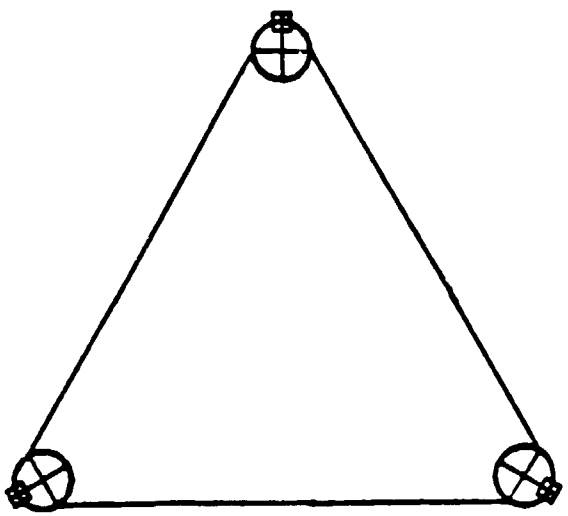
SPACE27
FUSELAGE PROFILE
(ELEVATION PLANE)



S. F. = 200.000

Figure III.3-25. Three axial slot antennas on each module, with two diagonal solar panels and bottom truss platform. Side view.

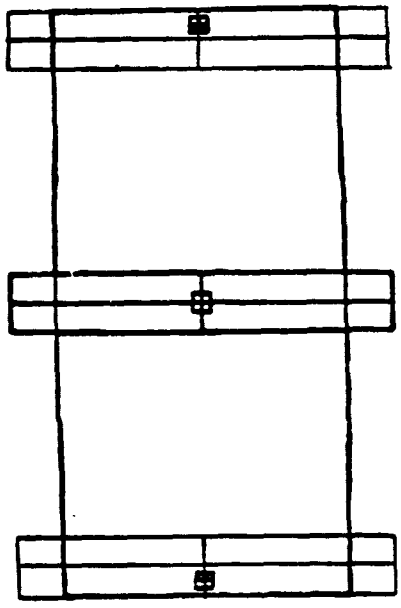
SPACE27
CROSS SECTION
(ROLL PLANE)



S. F. = 200.000

Figure III.3-26. Three axial slot antennas on each module, with two diagonal solar panels and bottom truss platform. Front view.

SPACE27
HEADING PROFILE
(AZIMUTH PLANE)



S. F. = 200.000

Figure III.3-27. Three axial slot antennas on each main module, with two diagonal solar panels and bottom truss platform. Top view.

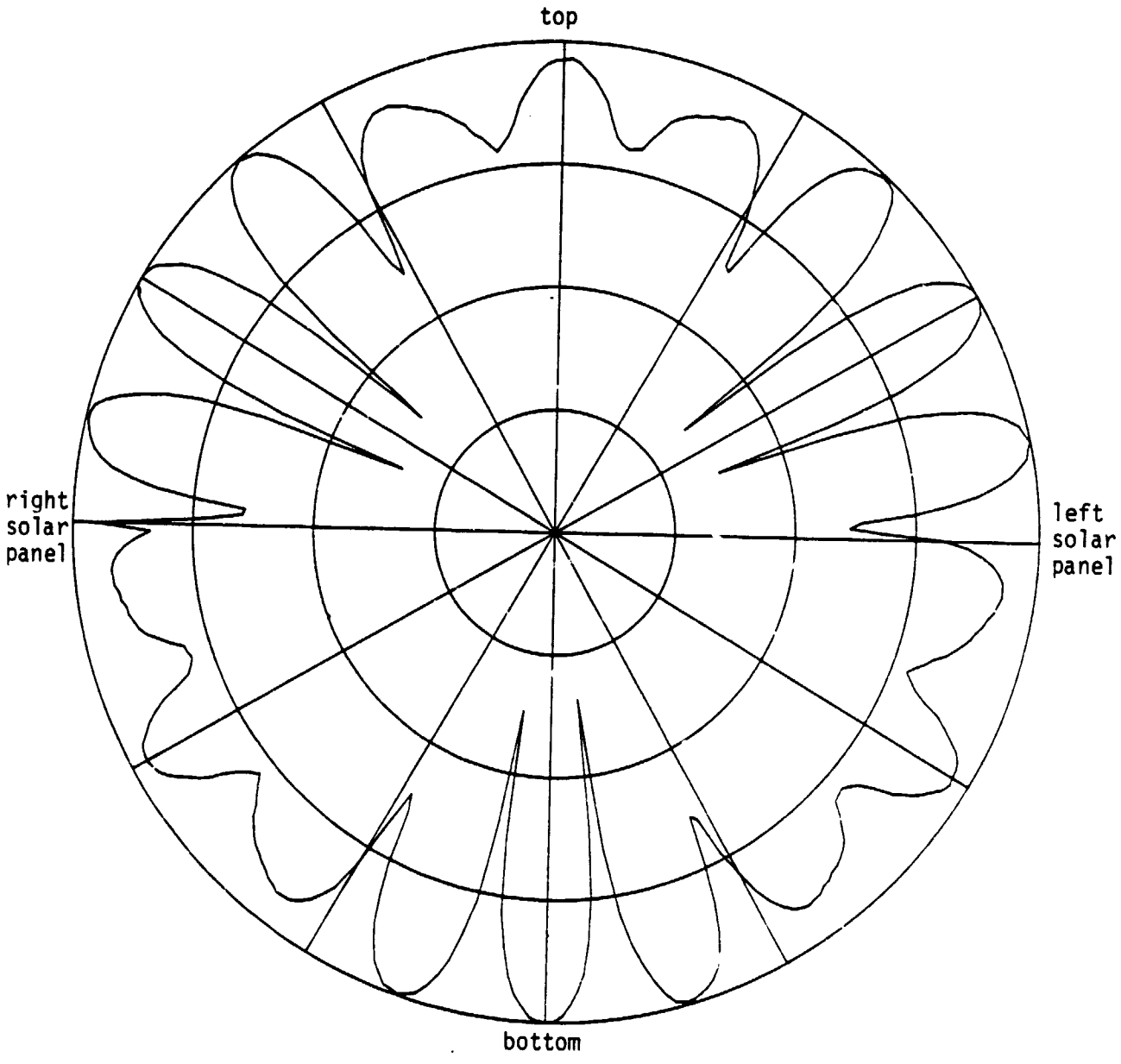


Figure III.3-28. Principal roll plane pattern at .26 GHZ. Three axial slot antennas on top of each module.

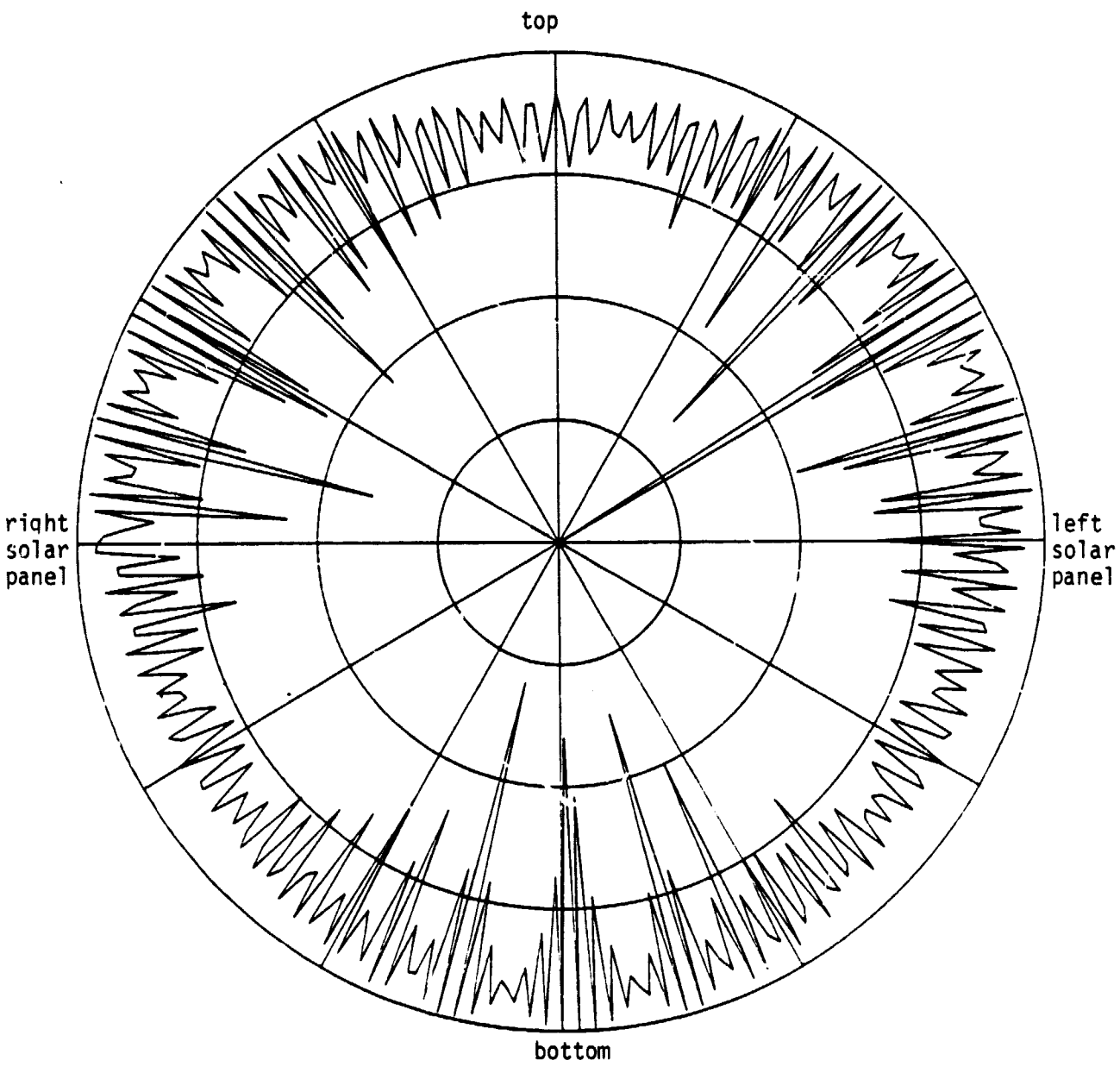


Figure III.3-29. Principal roll plane pattern at 2.2 GHZ. Three axial slot antennas on top of each module.

E-PHI
DB PLOT

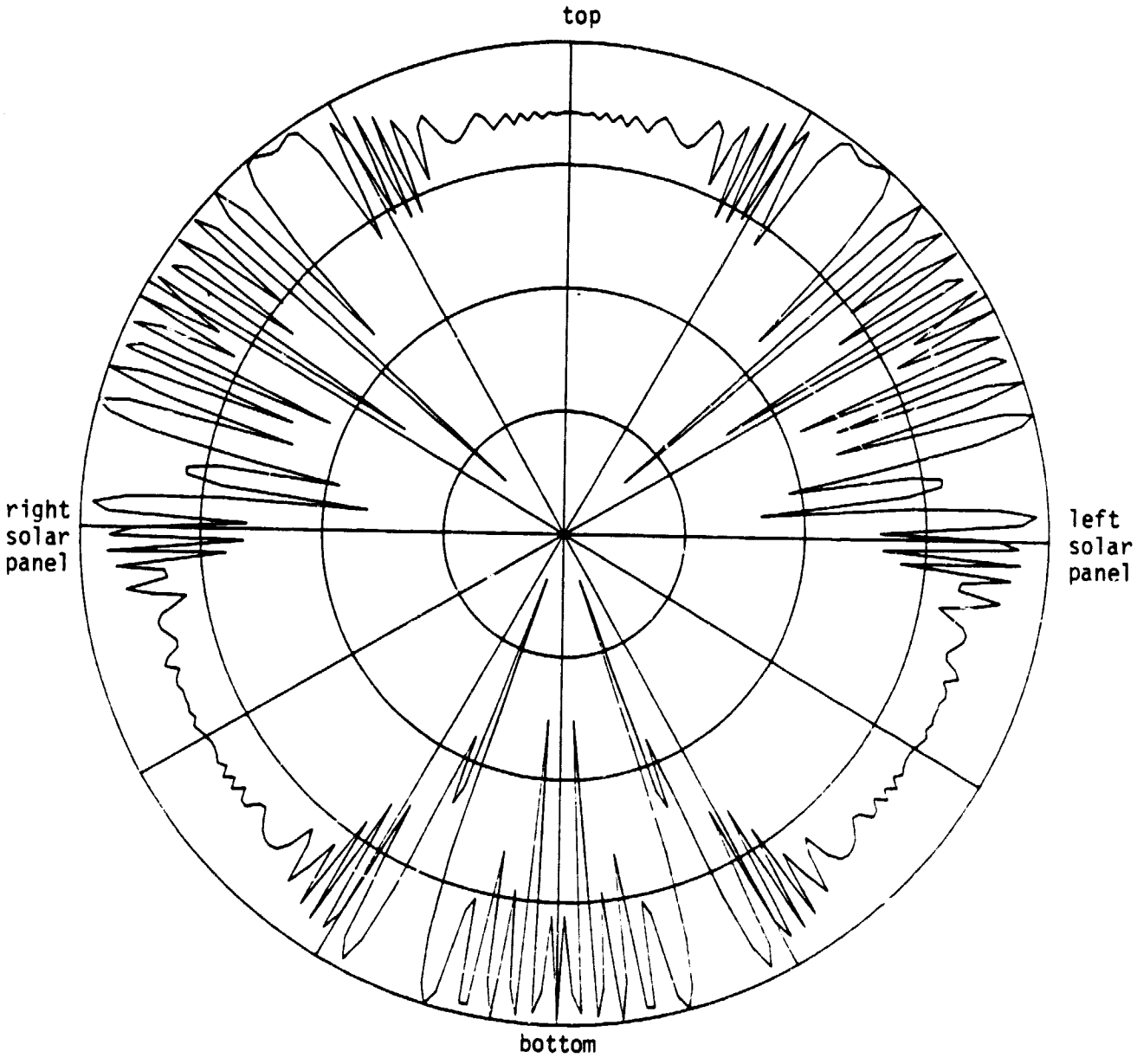


Figure III.3-30. Principal roll plane pattern at 25 GHZ. Three axial slot antennas on top of each module.